

PHYSIOLOGY
FOR THE
LABORATORY

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PREFACE.



It has seemed to me that there is needed a radical change in the teaching of physiology. The old way of teaching physiology merely from the text-book has been outgrown in most of the best schools. Many teachers are in the next stage of development. They use the text-book largely, but have experiments to illustrate the text. That is, they use first the text-book, and secondly the experiments.

It would seem that the logical way to teach the elements of physiology, as the elements of other sciences, would be, first, to study the specimen and then to go to the text-book for additional facts after we have thoroughly laid the foundation with the specimens. The text-book should be used, but the foundation must first be laid from the study of the actual animals in the laboratory. This has long been the method of teaching botany, chemistry, and the other sciences. Why should physiology be taught so very differently? Some have thought that the subject was not one for experimental work in the high and normal schools. But that can be easily disproved by visiting some really good teaching in this subject. The student's own body may be studied to a certain extent, and then

the markets furnish us with the parts of many lower animals that may be used to teach the functions of corresponding parts of the human body.

The ideal way to teach physiology, of course, would be to give the specimen to the student and expect him to discover for himself the structure and function of all the parts. This was Agassiz's method. But this is hardly practicable to-day. With so much to teach and so short a time to do it, we must necessarily help the student. We may call his attention to the important things to be seen and then make sure that he has found them correctly. With a large class, the simplest way to call attention to the main points is by clear and well-written directions to be used in the laboratory. We can only be sure that each one finds the parts when he shows them to us, or we examine his carefully labeled drawings. The directions should not be too full. They should simply point the way and not describe the parts. That is the work of the student. If the directions are too full, or the ordinary text-book is used in the laboratory, the beginner is tempted to study the text-book and disregard the specimen.

Too much stress cannot be laid on the importance of gaining the first impressions from the specimens. This has already been too long neglected in the teaching of physiology. We must also bear in mind that we are not teaching this subject merely for the sake of anatomy and physiology as sciences, but for the sake of hygiene and better ways of living.

Finding that much time may be lost in the laboratory unless the work is carefully planned, I have found it convenient, in my own classes, to use a series of directions

that may prove of service to some other teacher. All of the experiments are simple and may be performed by any student. Most of the apparatus is made by the students, and no elaborate pieces are required. The other supplies are such as may be obtained from the ordinary market, or are similar to those found in any simple chemical or physical laboratory.

I have to thank Mr. C. B. Wilson of the State Normal School at Westfield, Mass., and Dr. Theodore Hough of the Massachusetts Institute of Technology, for carefully reading the manuscript and making some valuable suggestions.

B. M. B.

BOSTON, MASS., April, 1900.



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CONTENTS.



CHAPTER	PAGE
I. GENERAL DIRECTIONS. THE MICROSCOPE . . .	1
II. THE CELLS	7
III. THE BONES	9
IV. THE PREPARATION OF A SKELETON	16
V. THE JOINTS	18
VI. THE MUSCLES	22
VII. THE BLOOD	31
VIII. THE CIRCULATION	35
IX. RESPIRATION	49
X. THE TEETH AND THE TONGUE	55
XI. OTHER DIGESTIVE ORGANS	58
XII. FOODS	67
XIII. DIGESTION	77
XIV. THE KIDNEYS	87
XV. THE SKIN AND BODILY TEMPERATURE	89
XVI. THE BRAIN	94
XVII. THE SPINAL CORD AND OTHER NERVES	106
XVIII. THE EYE AND VISION	113
XIX. THE EAR AND HEARING	125
XX. SOME DERMAL SENSATIONS	127
XXI. THE LARYNX AND THE VOICE	130
XXII. BACTERIA	134
APPENDIX	147

“What is the range and position of Physiological Science as a branch of knowledge, and what is its value as a means of mental discipline? Its subject-matter is a large moiety of the universe; its position is midway between the physico-chemical and the social sciences. Its value as a branch of discipline is partly that which it has in common with all sciences — the training and strengthening of common sense; partly that which is more peculiar to itself — the great exercise which it affords to the faculties of observation and comparison; and, I may add, the exactness of knowledge which it requires on the part of those among its votaries who desire to extend its boundaries.”

HUXLEY.

“The great benefit which a scientific education bestows, whether as training or as knowledge, is dependent upon the extent to which the mind of the student is brought into immediate contact with facts — upon the degree to which he learns the habit of appealing directly to Nature, and of acquiring through his senses concrete images of those properties of things which are, and always will be, but approximatively expressed in human language.”

HUXLEY.

PHYSIOLOGY FOR THE LABORATORY.



I.

GENERAL DIRECTIONS.

THE COMPOUND MICROSCOPE.

IN studying the various parts of the human body, we need to magnify some of them in order to see their structure. To do this, we shall need to use a compound microscope. But, in the first place, it would be well to study the microscope and learn how to use it properly.

A. The Parts of the Compound Microscope.

The parts of the compound microscope are the **stand**, the **objectives**, and the **eyepieces**.

I. THE STAND.

The stand is the largest part of the microscope and includes all except the objectives and the eyepieces. It has several divisions :

a. The **foot**. The foot is the horseshoe-shaped part on which the rest of the microscope stands (Fig. 1, *a*).

b. The **pillar**. This is the vertical column that is fastened to the base (Fig. 1, *b*).

c. The arm. The arm is attached to the upper part of the pillar and supports the parts, *d* and *e*, of the microscope (Fig. 1, *c*).

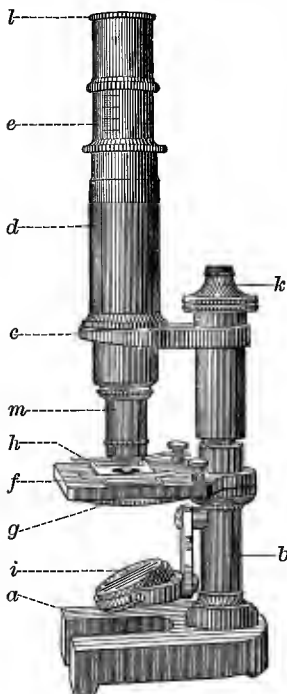


FIG. 1. — The compound microscope. *a*, foot; *b*, pillar; *c*, arm; *d*, body; *e*, draw-tube; *f*, stage; *g*, diaphragm; *h*, clips; *i*, mirror; *k*, milled head for fine adjustment; *l*, eyepiece; *m*, objective.

d. The body. This is the short outer tube upheld by the arm (Fig. 1, *d*).

e. The draw-tube. This is the long tube within the body to which the objectives and the eyepieces are attached. It is called the draw-tube, because in some microscopes it can be lengthened and shortened to change the magnification (Fig. 1, *e*).

f. The stage. This is the part attached to the pillar, below the body, on which the slide that is to be examined is placed (Fig. 1, *f*).

g. The diaphragm. Attached to the lower side of the stage is a circular piece, the diaphragm. It contains openings of different sizes and may be turned so that the one of the desired size may

be brought under the opening in the centre of the stage (Fig. 1, *g*).

h. The clips. These are the two small metallic pieces, one on either side of the stage, to hold in place the slide

to be examined (Fig. 1, *h*). These are merely for convenience and are not always used.

i. The mirror. The mirror is below the stage (Fig. 1, *i*).

k. The milled head. This is at the upper end of the pillar (Fig. 1, *k*). It is the fine adjustment to raise and lower the body of the microscope and all the parts that the body carries. Turn the milled head slowly and notice the motion of the body of the microscope.

II. THE OBJECTIVES AND THE EYEPIECES.

a. There are several objectives and eyepieces, but the objectives most often used are a low power No. 3 and a higher power No. 7. The eyepieces most often used are a low power No. 2 and a higher power No. 4.

b. The magnifications for the Leitz microscope are approximately as follows :

Objective 3	Eyepiece 2	Diameters 70
" 3	" 4	" 105
" 7	" 2	" 440
" 7	" 4	" 625

c. An object should first be examined with the low power, and afterward studied more carefully with the high power. The lenses must be perfectly clean, since the least dust or cloudiness obscures the image. For wiping the lenses use a soft cloth, first breathing upon the glass in order to dampen it. An old handkerchief is useful. The lenses should never be touched with the fingers, for they are apt to make ineffaceable marks.

B. The Use of the Microscope.

1. The stand is used with the ends of the horseshoe-foot pointing away from the student. It is always kept in this position, and any change in the light is overcome by a change in the position of the mirror.

2. The light is obtained by turning the mirror so that it will reflect the light from the sky upward through the draw-tube ; the amount of light may be regulated by the diaphragm. The sun should never be allowed to shine directly on the mirror or on any other part of the microscope.

3. The proper focus is found by two adjustments.

a. The coarse adjustment is used first with both low and high power to find the approximate focus. It is accomplished most easily by slowly twisting the entire draw-tube while sliding it upward or downward with the fingers.

b. The fine adjustment is used to focus exactly, so that the object shall be perfectly clear and distinct. It is effected by turning the milled head on the upper end of the pillar.

c. Never focus downward with the eye at the microscope, as there is danger of touching the slide with the lens and injuring both the slide and the lens.

d. If the object cannot be brought clearly into view by the adjustment, test the illumination by changing the position of the mirror, examine the objective to make sure that it is not wet, and finally examine the cover-glass.

e. Learn to keep both eyes open ; the strain upon them is far less than if one eye is closed. If the object does not

show clearly, do not strain the eye to see it, but change the focus by the fine adjustment.

4. Study the microscope until you are familiar with the names and uses of the various parts.

5. Make a sketch of the microscope and carefully label the parts.

NOTE. — The Leitz microscope and only the lenses that are most frequently used are here described. The general description, however, would apply to any other manufacture, but each kind has its own system of magnification.

In the microscopes made by the Bausch and Lomb Optical Co., the objectives and eyepieces are designated by their focal distances. The low-power objectives range from a focal distance of 3 inches (the lowest) to $\frac{3}{4}$ inch. The higher objectives range from a focal distance of $\frac{1}{2}$ inch to $\frac{1}{20}$ inch (the highest). The eyepieces range from a focal distance of 2 inches (a low power) to $\frac{1}{2}$ inch (a high power).

C. The Sketches and Records of Experiments.

I. SKETCHES.

All the more important observations should be recorded by sketches.

a. The outlines may be first traced lightly.

b. When all the parts are drawn, the outlines may be darkened with a hard pencil (H H H H) and the various parts made clear when necessary by the use of colored crayons or water colors.

c. Draw on a large scale and label neatly at the side of the drawing.

d. Do not shade your drawings so as to conceal the essential parts.

II. THE RECORD OF EXPERIMENTS.

After performing any experiment make a **record** of it in the following order :

- a.* The materials used.
- b.* The apparatus used.
- c.* The experiment, or what was done.
- d.* The observation of what occurred.
- e.* The inference, or explanation.

III. THE INSTRUMENTS.

Each scholar should be provided with a set of instruments consisting of :

1. A pair of scissors.
2. A pair of forceps.
3. A medium-sized scalpel.
4. Two needle-holders with needles.

Care should be taken to clean the instruments after using them, to wipe, and to keep them dry.

II.

THE CELL.

A. Simple Cells.

Material. A prepared slide showing large cells.

Apparatus. A compound microscope.

Study first with a low power and then with a high power a prepared slide showing large cells, as the cells of the cast-off skin of a newt, that have been stained.

Notice :

I. A SINGLE CELL.

- a.* Its general shape.
- b.* The **protoplasm**, lightly stained.
- c.* The **nucleus**, deeply stained.
- d.* The **nucleolus**, a dark spot in the nucleus.
- e.* Deeply stained loops, or **chromatin** loops, may be scattered through the protoplasm. This is the part that is thought to bear the hereditary characteristics.
- f.* The **cell-wall**, when present, on the outside of the cell.

II. THE ARRANGEMENT OF THE CELLS.

- a.* What is the general arrangement?
- b.* Are there any spaces between the cells?
- c.* Sketch several cells and label all the parts.

B. Cells of Other Tissues.

Material. Prepared sections of skin, connective tissue, fatty tissue, and cartilage. A section of skin from the roof of a rabbit's mouth will show I, II, and III finely.

Apparatus. A compound microscope.

Examine, in the same way as in A, prepared sections of the skin, connective tissue, fatty tissue, and cartilage.

Notice:

I. EPITHELIAL TISSUE.

- a.* Is it composed of cells or fibres?
- b.* How are they arranged?
- c.* Notice the change in shape and structure as we proceed from the inside outward.

II. CONNECTIVE TISSUE.

- a.* Is it cellular or fibrous?
- b.* What does its structure suggest as to its use?

III. FATTY, OR ADIPOSE TISSUE.

- a.* Where is it found?
- b.* Compare the cells with those of epithelium.
- c.* Do you find any nucleus? The protoplasm has been changed to oil.

IV. CARTILAGE.

- a.* The scattered condition of cells.
- b.* Do you find nuclei or cell-wall?
- c.* The substance intervening between the cells is neither cellular nor fibrous.

III.

THE BONES.

A. The Shapes of Bones.

Materials. A human skeleton and human vertebræ of the dorsal, lumbar, and cervical regions. Many different kinds of bones, as the leg and wing bones of chickens, the shoulder-blades and skulls of dogs and horses, bones of the ankle of sheep, and the vertebræ of chickens.

Study the bones of the human skeleton when possible, but the corresponding bones of other animals, as the dog, horse, and chicken, may be used for some of the experiments.

Select from the bones on the table :

a. A long bone.

1. What is its general shape ?
2. Compare with the human skeleton and find other long bones.

b. A tabular or plate-like bone, as the shoulder-blade.

1. What is its general shape ?
2. Compare with the human skeleton and find other tabular bones.

c. A short bone, as one of the wrist bones, having about the same diameter in every direction.

1. What is its general shape?
2. Compare with the human skeleton and find other short bones.

d. An **irregular** bone, such as the vertebra or any bone except the three preceding kinds.

1. Find other irregular bones in the human skeleton.

B. The Gross Structure of a Long Bone.

Materials. A long bone, as the humerus or bone of the upper arm; a fresh long bone, as the bone of the leg of a sheep. This should be sawed in halves longitudinally (lengthwise). Any butcher will saw the bone when the material is purchased.

Study carefully any long bone, as the humerus or bone of the upper arm. Most of the external parts may be seen from a dried specimen. Then compare this with a longitudinal section of a fresh bone and identify the remaining parts.

I. THE EXTERNAL PARTS (of a long bone).

a. The **shaft**, or long central cylindrical portion.

1. The **ridges** on the surface: their use? where do they lead?
2. The round **openings**: where situated? their use?
3. The **rough** places: what is attached here?
4. The **periosteum**, or covering on the fresh bone.
 - (1) How far does it extend?
 - (2) What is the color and appearance of its surface?
 - (3) What is its use?

b. The **articular extremities**.

1. How are these united to the shaft? (See a bone that has been boiled until the extremities have separated from the shaft.)
2. The **cartilage** in the fresh bone.
 - (1) How far does it extend?
 - (2) What is its texture and color?
3. The large **prominences** or knobs: their use?

c. Sketch and label all the external parts.

II. THE INTERNAL PARTS.

These may be seen from a longitudinal section of a fresh bone of the leg of a sheep.

a. The **hard** bone on the outside.

1. Note the thickness in different parts of the bone.
2. Where is it thickest? Why?
3. Where is it thinnest? Why?

b. The **spongy** bone in the ends.

1. How far does it extend?
2. What is its color in the fresh bone? That is due to the marrow within it.

c. The **fine cavities** and passages: their use?

d. The **medullary cavity** in the centre.

1. What is its shape?
2. How far does it extend?
3. Which is stronger, a solid or a hollow shaft containing the same amount of material?
4. What, then, is the use of the medullary cavity?

- e.* The marrow is within the cavity. What is its color? What is its use to the bone?
- f.* Make a sketch of the longitudinal section.

C. The Gross Structure of an Irregular Bone, a Vertebra.

Materials. A dorsal vertebra of the human skeleton or of a dog, sheep, or other vertebrate. The axis, or second cervical vertebra, of the human skeleton. The atlas, or first cervical vertebra, of the human skeleton. The spinal column just taken from a fresh fish or a rabbit.

1. Examine carefully a human vertebra of the dorsal region. If that is not possible, study the vertebra of a cat, a dog, a bird, a sheep, or of any other of the vertebrates. Identify the following parts when present:

- a.* The **centrum**, or body, is the large solid part.
- b.* The **neural arch** is the bony arch on one side; its use? Study the spinal column of the human skeleton and see whether the arch is on the dorsal (back) or ventral (front) side of the vertebral column.
- c.* The **neural ring** is formed by the neural arch and the centrum.
- d.* The **neural canal** is the cavity within the ring. See a fresh specimen of the spinal column of a fish and find what is in the neural canal.
- e.* The **spinous process** is the outward projection on the dorsal side of the neural arch.
- f.* The **transverse processes** are projections at the side.
- g.* The **anterior articular process** is the projection by which the vertebra joins the next vertebra above towards the head.

h. The **posterior articular process** is the projection by which the vertebra joins the next vertebra below.

i. Is there a medullary cavity in the vertebra?

j. Is there any spongy bone?

k. Does an irregular bone, then, have a medullary cavity or spongy bone?

l. Sketch a side and an end view of a vertebra.

2. Compare with the dorsal vertebra the following:

a. The **axis**, or second cervical (neck) vertebra, of the human skeleton or of a sheep. The **odontoid process** is the rounded prominence upon it.

b. The **atlas**, or first cervical vertebra.

c. What parts are present and what parts are wanting in each?

d. Place the axis in position on the atlas and find the use of the odontoid process.

e. Sketch an end view of each.

D. The Chemical Composition of Bone.

Materials. A thin piece of bone about two inches long. Hydrochloric acid, ten per cent. Ammonium hydrate. A long, slender bone, as a rib of a chicken.

Apparatus. A pair of Fairbanks standard scales. Bunsen burner. A piece of wire gauze about six inches square. A tall, slender jar. A ring-stand.

All bones are composed of animal and mineral matter.

I. THE MINERAL MATTER.

a. Weigh carefully a clean piece of bone.

b. Burn it on a piece of sheet-iron over the flame of a

Bunsen burner until it turns white. Be very careful neither to lose any of it nor to burn it too long.

- c.* What happens?
- d.* Touch it ; what happens?
- e.* What is its chief structure and general appearance?
- f.* What have you left?
- g.* Weigh it.
- h.* Calculate the amount of mineral matter in the bone.
- i.* What has become of the animal matter?
- j.* Calculate the amount of animal matter in bone.
- k.* Place the burned bone in dilute, ten per cent, hydrochloric acid.
- l.* What happens? Why?
- m.* Add ammonium hydrate (ammonia) in excess.
- n.* What happens? Why?

The mineral matter consists of eighty-three per cent of calcium phosphate, $\text{Ca}_3(\text{PO}_4)_2$, thirteen per cent of calcium carbonate, CaCO_3 , and of other salts. The animal matter consists mainly of an albuminoid, ossein, or collagen, which may be converted by boiling with water into gelatin.

II. THE ANIMAL MATTER.

a. Place a long, slender bone, such as a rib-bone, in dilute, ten per cent, hydrochloric acid in a tall, narrow jar, and leave it for a day or longer according to the size of the bone. Dilute nitric acid or vinegar may also be used.

- b.* Touch it ; can you bend it?
- c.* What are its characteristics now?
- d.* What has taken place?
- e.* What have you left?

f. Where is the mineral matter? Prove it.

g. Burn this as you did the entire bone. What previous experiment does this verify?

E. The Microscopical Structure of Bone.

Material. A prepared slide showing a cross-section of a human humerus.

Apparatus. A compound microscope.

Examine under the microscope a prepared cross-section of a long bone, as the human fibula or humerus.

a. Notice with the low power:

1. The large **Haversian canals** that are cut across.
These are the passages for the blood-vessels.
2. The **lamellæ**, or layers arranged concentrically around the canals.
3. The **lacunæ**, or small cavities separating the lamellæ. What is their shape? These were once filled with living cells. Why are they now black?
4. Sketch.

b. Notice, in addition, with high power:

1. The **canaliculi**, or wavy branches which run across the lamellæ.
 - (1) Where do they lead?
 - (2) What is their use?
2. Sketch.

IV.

THE PREPARATION OF A SKELETON.

A part of a skeleton, the wing or the leg of a fowl, makes a good specimen to mount. This exercise may be postponed until later, and some of the material obtained for the study of muscles be utilized. The skeleton of an entire animal may be prepared if each scholar will take one part.

Materials. A leg or wing of a chicken or bones to be mounted. Ammonium hydrate. Borax.

Apparatus. Bunsen burner. Ring-stand. A piece of wire gauze six inches square. Granite-ware stew-pan. Fine gimlet and wire or cardboard, needle and thread.

In preparing bones, only general directions can be given, as the kind, size, and condition of the bones determine, to a certain extent, the details.

a. Much of the muscle and fat may first be removed with scissors and scalpel.

b. Place the bones and the remaining débris in water and boil until the muscles fall readily from the bones. If a small amount of ammonium hydrate or borax be added to the water, the process will be facilitated. To remove the marrow from a long bone, bore a hole in either end and thoroughly wash out the marrow.

c. Place in clean water and remove everything from the

bones. Take care that none of the bones are lost, and notice the positions of the different bones.

d. Wash the bones repeatedly in fresh water until perfectly clean and then place them on a board to dry.

e. Small bones may be sewed in their proper positions on a piece of stiff cardboard. Large bones should have a single hole bored at either end and be wired together. For the positions of the holes, study a skeleton that has been set up.

V.

THE JOINTS.

A. The Kinds of Joints.

Materials. The human skeleton. The student's body.

Study carefully the human skeleton and identify the four kinds of joints.

a. A ball and socket joint, *e.g.* the hip-joint.

1. What are all the possible movements?
2. What is the shape of the different parts of the joint?
3. Find other joints of this kind.

b. A hinge joint, *e.g.* the knee-joint.

1. How many movements has it?
2. What is the shape of the different parts of the joint?
3. Find other hinge joints.

c. A pivot joint, *e.g.* between the first and second cervical vertebræ.

1. What is the motion?
2. How is the joint formed?
3. Can you find other pivot joints?

d. A gliding joint, *e.g.* between the bones of the wrist, — the carpal bones.

1. What is their motion?
2. Find other joints of this kind.

B. A Ball and Socket Joint.

Material. A fresh hip-joint of an ox or sheep with the membrane and muscles still attached. If the butcher saws it in halves longitudinally, the different parts may be clearly seen.

Study carefully a large, fresh ball and socket joint, such as the hip-joint of a sheep.

Identify:

a. The cavity, or **acetabulum**. What is its shape and use?

b. The ball, or head of the long bone. What is its shape and use?

c. The **cartilage**.

1. How far does it extend?
2. Feel of it.
3. Cut it.
4. What are its properties and uses?

d. The **ligaments** bind the bones together. Find the use and the properties of each.

1. The **capsular** ligament is a loose bag extending all around the joint.
2. The **round** ligament passes from the acetabulum to the head of the long bone. How does the attachment of these ligaments allow motion at the joint?

e. The **tendons** attach the muscles to the bones. How do they differ in appearance from the ligaments?

f. The **synovial** membrane is a thin layer of cells extending over the ligaments and cartilage. It is too thin to be distinguished with the naked eye.

g. The **synovial liquid** is found as soon as the capsular ligament is cut. It is secreted by the synovial membrane.

1. Rub a little between your fingers.
2. What is its use?

h. Sketch and label all the parts.

C. Some Other Joints.

Material. The fore leg of a lamb.

The joints of the fore leg of a lamb may be studied.

1. Compare the fore leg of the lamb with the upper limb of man and find which joint you are studying. Describe the way in which the bones fit together at the joint, and explain how motion in certain directions is prevented while it is allowed in others.
2. Identify the different parts of the joint that are named under the ball and socket joint, except *a* and *b*. Sketch.

D. The Microscopical Structure of Cartilage.

Material. A prepared slide of hyaline cartilage.

Apparatus. A compound microscope.

Study with the high power of a compound microscope a prepared slide of a piece of hyaline cartilage.

Notice:

1. The cartilage cells.
 - a.* What is their shape?
 - b.* How are they arranged?
 - c.* What parts of the cell can you identify?

2. The homogeneous material, or **matrix**, in which the cells are embedded. Sketch.

E. The Relation of Cartilage to Bone.

Materials. A prepared slide of developing bone. Foetal bones of some young animal. (Those of the pig are usually easy to obtain from any butcher.)

Apparatus. A compound microscope.

Study:

1. Some of the long bones of the foetus.
 - a. Examine them both in the centre and at the ends. Compare in structure and density.
 - b. Compare them in shape with the adult form.
 - c. Compare them with cartilage joining the ribs to the breast-bone and with cartilage always present at the joints.
2. Examine the prepared slide of developing bone.

Notice:

- a. The enlargement and rearrangement of cartilage cells.
- b. The calcification of the matrix.
- c. Sketch.

VI.

THE MUSCLES.

A. The Parts of a Muscle.

Material. A chicken, pigeon, or fore leg of a lamb.

Examine the muscles of some small animal, as a chicken, a pigeon, or the fore leg of a lamb. Dissect carefully one entire muscle, but do not cut it away.

Notice :

a. The **belly** is the red central part.

1. What is its shape when contracted ?
2. What is its shape when relaxed ?

b. The **tendons** are attached at either end.

1. What is their texture ?
2. What is their use ?

c. At how many places is a muscle attached ?

d. The **origin** is the less movable attachment of the muscle.

e. The **insertion** is the more movable attachment of the muscle.

f. Which is the origin and which is the insertion of the muscle that you have dissected ?

g. Sketch.

B. The Gross Structure of a Muscle.

Material. A piece of lean corned beef about two inches long.

Some of the parts of a muscle may be seen especially well in a piece of corned beef.

a. The **perimysium**, or loose sheath, is on the outside of the entire muscle.

1. Of what is it composed?
2. What is its color?
3. What is its use?
4. What relation does it bear to the tendons?
5. Where do branch partitions from the perimysium extend?

b. A muscle is composed of many bundles of tissue or **fasciculi**.

c. **Smaller fasciculi** unite to form a larger fasciculus.

d. The smaller fasciculi are composed of **fibres**. Tease out a few fibres. Note their color, size, and shape.

e. The **nerves** are the fine white threads seen on the outside and sometimes within the muscles. What is their distribution and use?

f. The **blood-vessels** are the red or colorless thin-walled vessels usually found with the nerves.

g. Is a muscle a tissue or an organ? Why?

h. Sketch both longitudinal and transverse views.

C. The Different Kinds of Muscles.

Material. A fowl.

In a common fowl the different kinds of muscles may be found. The tendons of the muscles of the foot and of

the leg of a fowl should be dissected carefully, leaving their attachments at both ends. By pulling the upper ends of the tendons that are attached to the muscles of the fore leg, the toes will move as in a living fowl, and can be made to pick up objects.

Find as many as possible of the following kinds of muscles.

a. A **simple** muscle is enlarged in the middle and tapers towards either end.

b. A **biceps** muscle is divided into two parts at one end so that it has three tendons. Find the biceps in the leg of the fowl.

c. In a **penniform** muscle the tendon runs along the side of the muscle.

d. The tendon runs down the middle of the muscle in the **bipenniform** muscle. This kind may be found on the breast of the fowl.

e. Sketch one of each kind.

D. The Microscopical Structure of Muscles.

I. STRIATED MUSCLE.

Material. A prepared slide of striated muscle.

Apparatus. A compound microscope.

Study under the compound microscope a prepared slide of a few fibres of striated muscle that have been teased apart. Frog's muscle shows the striations very plainly.

Notice :

a. A single fibre.

1. Its shape.

2. The **striations** that run across the cell.

3. The **nuclei**.
4. The **sarcolemma** is the thin sheath on the outside.
Look for it where the fibre has been crushed or bent.
5. The longitudinal divisions of the fibre into many small **fibrillæ** are not always visible.
6. Sketch.

II. STRIATED MUSCLE. — A CROSS-SECTION.

Material. A slide showing a cross-section of striated muscle that has been hardened in Flemming's fluid and stained in safranin.

Apparatus. A compound microscope.

Examine with the high power of a compound microscope a cross-section of striated muscle.

Observe :

- a. The arrangement of the fibres in the muscle.
- b. The parts of a single fibre.
 1. The polyhedral areas into which the entire fibre is divided are the **areas of Cohnheim**.
 2. Each area is a group of bundles of **fibrillæ**. The granular appearance of each area of Cohnheim is due to the cut ends of the fibrillæ. The fibrillæ are arranged in columns or bundles which, taken together, make the fibre.
 3. Surrounding each fibrilla and again around the columns of fibrillæ is a hyaline or slightly granular substance resembling protoplasm, called **sarcoplasm**.

III. PLAIN MUSCLE.

Material. A prepared slide of the fibres of plain muscle.

Apparatus. A compound microscope.

Examine in the same way a piece of plain or non-striated muscle. Identify the different parts of the fibre-cell. Sketch.

E. Experiments on the Student's Body.

1. Examine carefully the back of your hand, bending and extending the fingers one by one.

a. Find the different tendons or cords and follow them outward. To what are they attached?

Notice especially:

1. The arrangement at the knuckles.
2. The tendon of the little finger. How is it connected with the tendon of the third finger? Why?

b. Follow the tendons inward toward the arm.

1. Where do they lead? Compare the tendons of the thumb and the little finger.
2. Where are the muscles to which these tendons are attached? Verify by placing your fingers on the muscles and bending the fingers as far back as possible.

c. Sketch.

d. Compare this with a drawing of the hand showing the muscles and tendons.

2. Notice the mass of muscles at the base of the thumb. Grasp a book tightly between the thumb and forefinger. What happens?
3. Pin a piece of paper snugly around the upper arm. Lift a weight to the shoulder. What happens? Why?

4. Standing with heels near together, rise on the toes and then sink as far as possible, bending ankles and knees. Repeat six or ten times. Explain.

F. The Way in which Muscles Act.

Materials. A frog. Ether. Cotton batting.

Apparatus. Ring-stand. Small induction coil. Battery. Wires, etc.

Etherize the frog, cut the spinal cord just back of the head and destroy the brain with a probe. Lay bare the gastrocnemius (calf) muscle in one hind leg with the nerve leading to it (the sciatic nerve), and cut the several branches of this nerve close to the backbone.

1. Stimulate the nerve, with a single shock, close to the backbone and watch results. Does the result follow instantaneously? Why? How long does it take the muscle to recover its normal position?
2. Stimulate at any point with a rapid succession of shocks. What difference is there in the result? Call this *tetanus*, and show its relation to convulsions and cramp. How long does it take the muscle to recover?
3. Expose the muscle and nerve on the other hind leg, cut, and repeat 1 and 2 to verify the results before obtained, watching especially the interval which elapses between stimulation and contraction.
4. Repeat the single shock stimuli many times at quite short intervals, allowing the muscle to recover each time. Note the decreasing strength of contraction produced and the increasing length of time it takes to recover. This is *fatigue*.

G. The Work of Muscles and Bones. Levers.

Apparatus. A wooden rod about a yard long. Weights of different sizes. A triangular prism of wood for a fulcrum. A spring-balance.

Arrange the different parts to show the kinds of levers. One weight will represent the "weight," and the spring-balance will measure the power. Change the weight and notice the effect on the power. The power arm is the distance from the power to the fulcrum, and the weight arm is the distance from the weight to the fulcrum. Find the relation of the product of the power and the power arm to the product of the weight and the weight arm.

Show the three kinds of levers:

- a.* When the fulcrum is between the power and the weight.
- b.* When the weight is between the power and the fulcrum.
- c.* When the power is between the weight and the fulcrum.

H. The Lever in the Arm.

NOTE. — These problems may be solved arithmetically or worked out on Dr. Fitz's lever apparatus.

1. The bones of the forearm act as a lever. Part of the power is the biceps muscle attached on the inside just below the elbow.
 - a.* Where is the weight? the fulcrum?
 - b.* What is the length of the power arm? of the weight arm?
 - c.* Which kind of lever is this?

d. How much power must be exerted to lift a weight of twenty pounds resting on the hand, when the forearm is in a horizontal position?

2. The triceps muscle of the back of the arm does part of the work of the arm. It is attached just back of the elbow-joint.

a. Where is the weight? the fulcrum?

b. Which kind of lever is this?

c. How much power must be exerted by the triceps muscle to make the hand push twenty pounds?

I. The Lever in the Foot and Leg.

When standing on the toes, the bones of the foot act as a lever. The power is in the muscles of the calf of the leg.

a. Where is the weight? How much is it?

b. How long are the power and the weight arms?

c. Which kind of lever is this?

d. How much power is required for a person weighing 125 pounds to stand on his toes? How much is required for you to stand on your toes?

J. A Model of an Arm.

NOTE. — This is adapted from Woodhull's Home-Made Apparatus.

Apparatus. One piece of wood 4 in. $\times$ 3 in. $\times$ 1 in.

“ “ 9 in. $\times$ 1 in. $\times$ 1 in.

“ “ 4 in. $\times$ 1 in. $\times$ 1 in.

Three rubber bands. Six hooks. Four small strips of tin about an inch long.

The general arrangement of the muscles in the arm may be obtained from a model of wood with muscles of rubber

bands. The model consists of three pieces of wood; the longest represents the humerus, the smallest represents together the radius and the ulna, and the broadest represents the shoulder-bone, or scapula. A rubber band

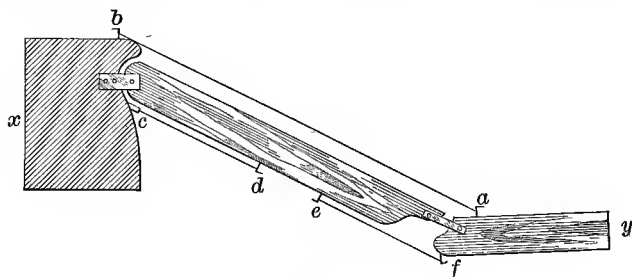


FIG. 2. — A model of an arm.

attached at *a* below the elbow-joint and at *b* above the shoulder-joint represents the biceps muscle. The rubber band attached at *e* and *f* represents the triceps muscle.

1. Adjust the three bands so that the arm hangs down straight. Show how the muscles work in opposition to each other over the joints. How is the joint made rigid?
2. Unfasten the band at *e* and *f*. What happens to the arm? What muscle causes this motion?
3. Replace the rubber band *ef* and unfasten the band *cd*. What happens to the arm? What muscle does the work?
4. If both *ef* and *cd* are unhooked, what is the position of the arm? What muscle causes this motion?
5. Remove the piece of wood representing the scapula, and readjust the muscles to represent the movements of the foot.

VII.

THE BLOOD.

A. The Structure of Blood.

Materials. A drop of human blood. To obtain a drop of blood, tie a string or wind a handkerchief tightly around the finger and wait a few minutes until the blood has collected in the finger. Then with a clean needle make a prick near the nail. Let a drop of blood fall on a glass slide. Spread out the blood very thin by placing a second glass slide over the first and rubbing it about. Then remove the second glass slide, place a cover-glass over the blood and the slide is ready for examination. A prepared slide of the blood of a frog.

Apparatus. Glass slides. Cover-glasses. Compound microscope.

I. THE HUMAN BLOOD.

Examine a drop of human blood under the microscope.

Notice :

- a.* The **red corpuscles**. What is their shape and arrangement?
- b.* The **white corpuscles**. What is their relative size and shape? What is their relative number?
- c.* The delicate threads of **fibrin**.
- d.* Sketch.

II. THE FROG'S BLOOD.

Study with the microscope a slide of the blood of the frog prepared by double staining to show the nuclei of the red corpuscles.

Notice :

a. The red corpuscles. What is their shape as shown by a surface and an end view? Do you find a nucleus?

b. The white corpuscles (stained in the preparation). What is their size and shape? What is the nature of their contents? Have they any nucleus?

c. Sketch a corpuscle of each kind greatly enlarged.

III. THE BLOOD OF OTHER ANIMALS.

A few drops of a pigeon's or a hen's blood may be obtained and compared with the two kinds already studied.

B. The Clotting of Blood.

Materials. Fresh blood from the market, or a frog. Chloroform. Cotton batting.

Apparatus. Test-tube. Bell-jar.

I. THE CLOT.

Fresh blood of an animal recently killed may be had of the butcher, or a frog may be killed and the blood collected. To kill a frog, place it under a bell-jar with some cotton batting saturated with chloroform. Wait until the frog is stiff before dissecting. Then make an incision along the ventral median line, cutting through the breast-bone. Cut the blood-vessels leading to and from the heart close to the latter, and collect the blood in a test-tube. Pour out some of the blood into a smaller test-tube and allow it to stand, taking care to cover it so that it cannot dry. Watch it until changes take place. In case the blood is obtained of the butcher, some of it should be poured in a glass jar and allowed to coagulate.

Notice :

a. The clot. What is its color, shape, size, consistency, and position?

b. The serum or straw-colored liquid. Where is it found? Compare it with the clot in quantity. Remove the serum and notice the effect on the clot.

II. FIBRIN.

Beat vigorously the remainder of the blood obtained of the butcher, with a bundle of twigs or wires, for a few minutes until some stringy elastic **fibrin** has collected upon them. Remove the twigs with the fibrin, rinsing them as much as possible in the whipped blood.

Notice :

a. The amount, form, and nature of the fibrin. Whence did it come?

b. What is its color? Rinse thoroughly under the faucet and note again the color. To what was the former color due? Compare with the color of clot in clotted blood. Inferences.

c. The liquid which remains after the fibrin has been removed. What part of the blood is it? What color is it?

d. Allow this liquid to stand for some time. Does it clot? To what, then, was the clotting in the other blood due? Compare this liquid carefully with the serum.

III. THE COMPOSITION OF BLOOD SERUM.

Material. Blood serum left after I.

Apparatus. Evaporating dish. Ring-stand. Wire gauze. Bunsen burner. Test-tube.

a. Allow any corpuscles that remain in the serum to settle and pour off some of the clear liquid. Evaporate this slowly to dryness.

1. How much residue is left? What does this represent?
2. Heat this residue as you did the bone until it is all burned. Is anything left? What kind of matter is it?
3. Moisten a piece of paper with serum and attempt to dry it. What must have been present in the serum? Whence did it come?
4. Boil a small amount about 10 c.c. of serum in a test-tube. What change takes place? What does this show?

C. The Influence of the Presence or Absence of Oxygen on the Color of Blood.

Material. Fresh blood in a small test-tube. The blood that was left after experiment B may be used.

Apparatus. A small test-tube. A piece of glass tubing six inches long.

Collect a small amount of blood in a test-tube.

- a.* What color is the blood?
- b.* Is it arterial or venous?
- c.* Breathe through a glass tube into the blood.
- d.* What occurs? Explain.

VIII.

THE CIRCULATION OF THE BLOOD.

A. The Heart and Related Organs.

Material. Obtain from the market the "pluck" of a sheep, pig, or calf. This includes the heart, lungs, trachea, and diaphragm. Care should be taken to engage it beforehand, with the request that it be left intact, or the heart will be punctured and there will be no pericardium.

Study the entire specimen.

Identify :

- a.* The lungs.
- b.* The trachea, or windpipe leading to the lungs.
- c.* The *œsophagus*, a thin-walled tube near the trachea, is sometimes cut away.
- d.* The heart.
- e.* The *pericardium* is the thin-walled bag in which the heart is held. Does it fit closely to the heart? Puncture the pericardium, if it has not already been cut.
- f.* The *pericardial liquid* is within the pericardium.
- g.* The *diaphragm* is the muscular membrane just under the heart. What is its shape and texture? Part of it may be cut away.
- h.* Sketch all the parts to show the relation of one to another.

B. The Parts of the Heart.

Materials. The heart and lungs of a calf with the pericardium removed.

Place the mass on the table with the heart uppermost and with the point of the heart extending away from you.

Now you see the front of the heart, or its ventral surface.

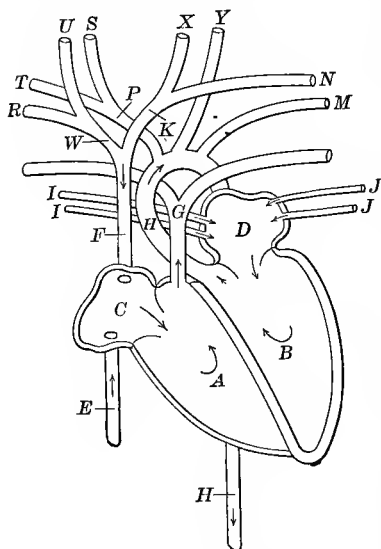


FIG. 3. — Diagram of the heart and large blood-

vessels. *A*, right ventricle; *B*, left ventricle; *C*, right auricle; *D*, left auricle; *E*, inferior vena cava; *F*, superior vena cava; *W* and *K*, right and left innominate veins; *R* and *N*, right and left subclavian veins; *U* and *X*, right and left jugular veins; *G*, pulmonary artery; *I* and *J*, right and left pulmonary veins; *H*, aorta; *P*, innominate artery; *S* and *Y*, right and left carotid arteries; *T* and *M*, right and left subclavian arteries.

Notice :

a. The **apex**, or the point of the heart.

b. The **base** of the heart is its large end.

c. The **ventral** surface, or front of the heart, is the side that is now uppermost as it lies on the table.

d. The **dorsal** surface is opposite the ventral. Which is more convex?

e. The **right** side of the heart is on your right as it lies on the table.

f. The **left** side of the heart is on your left. The two sides are separated by a groove. What is in this groove?

g. The **right ventricle** is

the large chamber of the heart on the right side of the heart. (*A* in Fig. 3.)

h. The **left ventricle** is the corresponding chamber on the left side. Which ventricle has thicker walls? Why? Do they both extend to the apex of the heart? (*B* in Fig. 3.)

i. The **right** and the **left auricles** are the thin-walled pouches at the base of the heart. They may be partly cut away in your specimen. (*C* and *D* in Fig. 3.)

j. Sketch a dorsal and a ventral view of the heart.

C. The Blood-Vessels that Open into the Heart.

Materials. The heart and lungs of a calf, neither cut nor punctured in any way, but with the pericardium removed.

Apparatus. A piece of glass tubing drawn out to a point for a blowpipe or a metallic blowpipe.

Identify:

a. The **inferior vena cava** is the large vein that comes up from the lower part of the body and carries the impure blood into the right auricle. Look for it on the dorsal side of the right auricle at its extreme left where it joins the right ventricle. With a blowpipe inflate the auricle through the inferior vena cava. (*E* in Fig. 3.)

b. The **superior vena cava** carries the blood from the upper part of the body into the right auricle. Look for it close beside *a*, but at the part of the right auricle that is farthest from the apex of the heart. Follow it away from the heart, as far as you can, to its source at the union of the two innominate veins. With the blowpipe inflate the auricle through this vein. (*F* in Fig. 3.)

c. The **pulmonary artery** leads from the base of the right ventricle to the lungs. Look for it on the ventral side of the heart between the two auricles. How far can you trace it? In what direction does it run? Explain this crossing. Does it carry arterial or venous blood? Why is it called an artery? (See *G* in Fig. 3.)

d. The **aorta** is the large tube leading from the left ventricle. Trace it from the heart and find the arch where it turns to go to the lower part of the body. (See *H* in Fig. 3.)

e. The four **pulmonary veins** run from the lungs to the left auricle. The two right pulmonary veins run close along the dorsal surface of the right auricle. The two left open at the extreme left of the auricle beneath the arch of the aorta. (See *I* and *J* in Fig. 3.)

f. Indicate the openings of the blood-vessels in your sketches of the heart.

g. Trace the path of the blood through the heart from the superior and inferior venæ cavæ.

h. Indicate in your sketches of the heart the path of the blood through it.

D. The Valves of the Heart.

Materials. The heart of the calf. Water.

Apparatus. A bulb syringe. A glass graduate.

I. THE TRICUSPID VALVE.

Cut away most of the right auricle and with a bulb syringe inject water or allow water from a faucet to flow into the right ventricle. Notice the action of the valves between the auricle and ventricle at the auriculo-ventricular orifice. Press on the ventricle to imitate its contrac-

tion. Where does the water escape? Cut through the wall of the ventricle from the base to the apex and spread it open, exposing the tricuspid valve.

Notice :

a. The flaps. How many are there and how are they arranged?

b. How are they held in place? The white cords are called *chordæ tendinæ*.

c. One end of these cords is attached to the edge of the valve. To what is the other end attached? These are the *papillary muscles*. Explain how they work. Why is something of this sort necessary?

d. Sketch.

II. THE SEMILUNAR VALVES AT THE BASE OF THE PULMONARY ARTERY.

Find where the pulmonary artery opens into the right ventricle. Cut away enough of the wall of the ventricle to see the opening from below. Pour water into the artery and watch the action of the valves.

Notice:

a. How many are there?

b. What is their shape?

c. What is their arrangement?

d. What effect did they have on the stream of water?

e. What effect did the water have on them?

f. Sketch.

III. THE MITRAL OR BICUSPID VALVE.

Remove the left auricle, noticing from the inside where the pulmonary veins open into it. Inject water into the

left ventricle as you did into the right and compare the valves with those of the right ventricle.

IV. THE SEMILUNAR VALVES AT THE BASE OF THE AORTA.

Find the opening of the aorta into the left ventricle and study the semilunar valves as you did those at the base of the pulmonary artery.

E. The Valves in the Veins.

Material. The heart and blood-vessels of a calf.

Apparatus. Knitting needle.

If the veins are still attached to the specimen, try to find the valves in them by passing down a small probe, as a knitting needle.

a. In what direction is the blood flowing in the veins? In what direction do the valves prevent flow?

b. Compare their action with that of the semilunar valves in the arteries.

Remove the heart and reserve the lungs and trachea . . for study another time.

F. The Beating of the Heart.

Materials. A frog. Chloroform. 20 c.c. normal salt solution.

Apparatus. Watch crystal. Watch. Bunsen burner.

Kill a frog with chloroform, and as soon as it is dead and the limbs are stiff make a cut along the ventral median line, cutting through the breast-bone. Take care not to

cut any large blood-vessels. Cut open, carefully, the pericardium and watch the action of the beating of the heart.

Observe :

- a.* The alternate beats of the two auricles and the ventricle.
- b.* The synchronous beats of the two auricles.
- c.* The ventricle during contraction is pale, and its apex is thrown forward and upward.
- d.* The pause or **systole** before the auricle contracts.
- e.* Count the beats in a minute.
- f.* Remove the heart from the body and place it in normal salt solution in a watch crystal, and see if it still beats.
- g.* Apply a gentle heat and watch the effect.
- h.* Count the number of beats.
- i.* Apply ice and watch the effect.
- j.* Count the number of beats.

G. The Circulation in the Web of the Foot of a Frog.

Material. A live frog or tadpole.

Apparatus. Glass slides. Cover-glasses. Piece of cork two inches square. Cloth. Pins. Compound microscope.

To show the circulation in the web of the foot of the frog, the foot should be spread out perfectly smooth and held in place. Take a very thin piece of cork about two inches square, and cut a hole about half an inch in diameter in the centre of it. Lay a glass slide over the opening. Spread out the foot on the slide over the opening, and secure it there by pinning narrow strips of cloth across the ends of the toes. The frog may be kept quiet by

wrapping it in a moist cloth and then in tea-lead, leaving one foot exposed. Cover the foot with a cover-glass, taking care to have water beneath it.

A tadpole is often easier to manage than a frog. Lay a tadpole on a glass slide and keep it still by winding a piece of moist cloth loosely around both the tadpole and slide. Cover the end of the tail with a cover-glass, taking care that there is water under the cover-glass.

Study under the microscope the circulation of blood through the capillaries of the web of a frog's foot or the tail of a tadpole.

Notice :

- a.* The **capillaries**, or small thin-walled blood-vessels.
- b.* The **red corpuscles** carried along in the stream. What is their shape and color?
- c.* The **white corpuscles**. What is their movement and position in the stream of blood?
- d.* At a branch in the capillaries, see how the red corpuscles are bent out of shape, and then resume their normal shape.
- e.* The cells in the **epidermis**.
- f.* The black **pigment** cells.
- g.* What is the color of the blood in a small vein or artery?
- h.* Sketch.

H. Experiments on the Student's Body.

Apparatus. A watch. A rubber band, or piece of twine.

1. Find the pulse in different places.
 - a.* In the wrist.
 - b.* In the thumb.
 - c.* In front of the ear, or the side of the face.
 - d.* Under the knee. Cross one knee over the other and watch the foot of the crossed knee. Explain.
 - e.* On the temple.
2. Count your pulse standing, sitting, lying down, and after running. How soon is the pulse normal after running?
3. Trace the veins and arteries on the back of the hand and in the wrist. How can you distinguish between the veins and the arteries?
4. Tie a rubber band tightly around your finger. Explain the result.
5. Press with a finger on the skin, and then lift the finger.
6. Listen for the sounds of the heart of another person.

I. The Demonstration of the Principles of Circulation.**I. UPON WHAT CIRCULATION DEPENDS.**

- a.* The beat of the heart.
- b.* The peripheral resistance, or the resistance to the flowing of the blood in the capillaries.
- c.* The long stretch of elastic tubing or blood-vessels.

II. THE NORMAL FLOWING OF THE BLOOD.

Material. Water, which may be slightly colored red if preferred.

Apparatus. A small force-pump. Two wooden pails.

660 c.m. pure rubber tubing, 12 m.m. in diameter.

1½ m. " " " 6 m.m. " "

560 c.m. " " " 5 m.m. " "

Three-way glass connecting tubing, Y-shape. Six large size, 12 m.m. in diameter, length of one arm 90 m.m.

Eight medium size, 6 m.m. in diameter, length of one arm 65 m.m.

Two medium size, T-shape tubing, 6 m.m. in diameter, length of one arm 65 m.m.

Sixteen small size, 4 m.m. in diameter, length of one arm 60 m.m.

64 c.m. glass tubing 12 m.m. in diameter.

192 c.m. " " 4 m.m. " "

Two pinch-cocks.

35 c.m. of glass rod 2 m.m. in diameter, or pieces of a fine sponge.

By means of an apparatus made of glass and rubber tubing, the principal phenomena of the circulation of the blood may be demonstrated. A small force-pump connected with one end of the apparatus represents the action of the heart. The large rubber tubing of one half of the apparatus represents the arteries, and of the other half the veins. The small passages in the sponge within the small tubing, between the two parts, represent the capillaries and cause the peripheral resistance. The difference in structure between the arteries and the veins may be more clearly shown, if the arteries are made of very elastic pure rubber tubing, and the veins made of less elastic tubing which has some linen fibres in its walls. The outlet at *H*

represents an injury to an artery, and a corresponding outlet in the other half represents an injury to a vein.

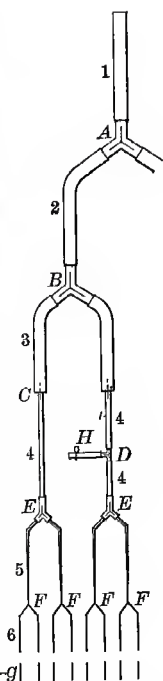
a. Connect the pump with the large artery, and slowly force the air out of the set of tubes, and water, slightly colored red, into the tubes. Imitate the action of the heart with seventy-two slight strokes a minute. Watch the circulation of the water through the tubing.

b. Hold in the hand a large artery and feel and count the pulse. Feel the pulse in a small artery. How do the two compare? Feel of a capillary. Is there any pulse? Feel of a small vein and then a large vein for the pulse. Where is the pulse most prominent? Where is it least felt?

c. Remove the stop-cock at *H* and continue the action of the pump. Is the outflow continuous or intermittent? How does the blood flow from an injury in an artery?

d. Remove the corresponding stop-cock in the large vein, and replace the stop-cock in the artery. Continue the action of the pump. Is the outflow continuous or intermittent? How does the blood flow from an injury in a vein?

e. How does the flowing of



half way-----g | | | | |

FIG. 4.—One fourth of the apparatus to illustrate the circulation of the blood. 1, 2, and 3 are of the 12 m.m. rubber tubing; 4 is of 6 m.m. rubber tubing; 5 and 6 are of 5 m.m. rubber tubing; *A* and *B* are the 12 m.m. three-way, Y-shaped, connecting glass tubing; *E* is a three-way, Y-shaped, glass tube; *F* is the 4 m.m. three-way, Y-shaped, glass tubing; *D* is a three-way, T-shaped, connecting glass tube; *C* is the connector made from 12 m.m. glass tubing, drawn down to fit the rubber tubing 6 m.m. in diameter; *g* is of the 4 m.m. glass tubing, which is filled with pieces of fine sponge, or with pieces of glass rod 2 m.m. in diameter.

the blood near the pump compare with the flow in the large tube at the opposite end of the apparatus? What is true of the flowing of the blood in the large arteries and veins?

III. THE USE OF THE PERIPHERAL RESISTANCE.

Material. Water. A small force-pump.

Apparatus. One metre of pure rubber tubing 12 m.m. in diameter.

Connect with the pump a long piece of elastic rubber tubing, and intermittently force water through it. Is the outflow intermittent or continuous? Compare with the result obtained when the peripheral resistance is present as in II c. What is the effect of the peripheral resistance? What is the advantage of a continuous flowing of blood in the body?

IV. THE USE OF THE ELASTIC WALLS OF THE TUBES.

Material. Water.

Apparatus. A small force-pump.

50 c.m. of glass tubing 12 m.m. in diameter.

6 c.m. of rubber tubing 12 m.m. in diameter.

Connect with the pump a piece of glass tubing, and intermittently force water through it. Is the outflow intermittent or continuous?

J. A Model to Show the Action of the Semilunar Valves.

Material. A piece of thick manila paper, three inches by six and a half inches, strong enough for sewing, and flexible enough to bend easily. A piece of white cloth about the same size. Water.

Apparatus. Two glasses. Needle and thread.

A model of the base of the aorta and the semilunar valves may be made of paper and cloth. The piece of

paper, rolled so that the short ends lap half an inch, represents the aorta. The three valves are nearly semicircular in shape, like the outlines in dotted lines in Fig. 5. Each one is two inches wide and two and a half inches deep. These valves are left free at their upper edges, which should be flat on the paper, and are sewed along the

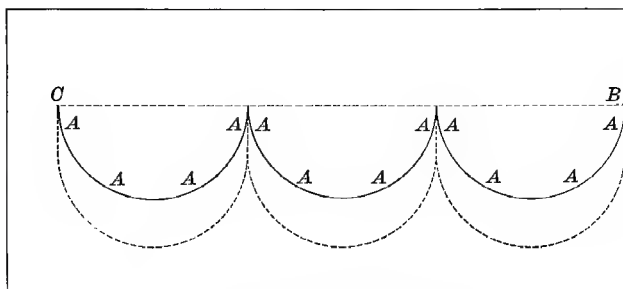


FIG. 5. — A model of the semilunar valves.

continuous line marked *A A A A*. After the valves are sewed in place, roll the paper so that *B* comes at *C* and sew. Make the model twice the size of Fig. 5.

1. Hold the model in the position corresponding to the aorta in the body. Are the valves placed upward or downward on the walls of the aorta?
2. Pour water through the tube to imitate the flowing of the blood through the aorta.
 - a.* What is the position of the valves?
 - b.* What is the effect of the valves on the stream of water or blood?

3. Imitate in a similar manner any backward pressure in the blood.

a. What is the effect of the water or blood on the valves?

b. What is the action of the valves?

c. What is the effect of the valves on the stream of water or blood?

d. Is your model perfect? If not, what condition of the valves does it illustrate?

IX.

RESPIRATION.

A. The Lungs of a Sheep.

Materials. The lungs and trachea of a sheep. A glass of water.

Apparatus. Blowpipe. Twine.

Study the lungs and trachea that have been reserved from a former exercise.

I. THE DIFFERENT PARTS.

Notice:

a. The lungs.

1. Their shape.
2. Their size.
3. Their color.
4. Their weight as compared with water. Cut off a small piece and place in water. Explain its action.

b. The trachea.

1. Its shape.
2. Its size.
3. The cartilaginous rings. What is their size, shape, and position. Do the rings reach entirely around the trachea? Why?
4. The lining membrane.

5. The two branches, or the right and the left bronchus.
6. Sketch both the lungs and the trachea.

c. Insert a blowpipe in the bronchus leading to the uncut lung, and tie a stout cord around it so tightly that no air can escape and inflate. Note the size of the lung before and after inflation. Of what kind of tissue must it be composed?

d. Dissect carefully one bronchus until its branches or bronchial tubes are found. Dissect one of the large bronchial tubes to the surface of the lung.

II. THE SUPPLY OF BLOOD.

Find where the pulmonary artery and a pulmonary vein enter one lung, and trace them as far as possible through the lung. Make a sketch of a portion of the lung dissected to show a bronchial tube, a vein, and an artery.

B. The Changes in the Air during Respiration.

Materials. Lime-water, about 250 c.c. Hydrochloric acid.

Apparatus. A thermometer. A glass tumbler. A bottle containing about 500 cc. A rubber stopper with two holes. Glass tubing to fit the holes in the stopper.

I. THE CHANGE IN TEMPERATURE.

a. Take the temperature of the air in the room.

b. Take the temperature of expired air by breathing on the bulb of a thermometer.

II. MOISTURE IN EXPIRED AIR.

a. Breathe on a cold glass.

b. What happens? Explain.

III. CARBON DIOXIDE IN EXPIRED AIR.

- a. Breathe through a tube into a glass of lime-water.
- b. What occurs? Explain and write the reaction.
- c. What occurs when hydrochloric acid is added?
- d. What does this prove?

IV. TEST THE AIR OF AN ORDINARY ROOM FOR CARBON DIOXIDE.

Use a bottle with a rubber stopper fitted with two pieces of glass tubing, each bent at a right angle. One piece of the tubing should reach nearly to the bottom of the bottle, the other just below the stopper. (See Fig. 6.)

a. Fill the bottle half full with lime-water.

b. Draw the air out of the bottle through the short tubing.

c. What happens? Why?

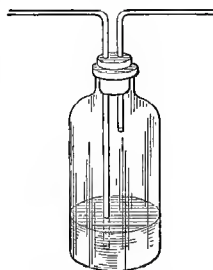


FIG. 6. — Apparatus for testing air for carbon dioxide.

C. Experiments on the Student's Body.

Apparatus. A watch. A tape-measure.

I. THE NUMBER OF RESPIRATIONS.

Count the number of respirations in a minute under ordinary conditions. Count the number after running.

II. THE SIZE OF THE CHEST DURING RESPIRATION.

Measure the chest by passing a tape across the chest and around just under the arms to the middle of the back.

Take a long, deep inspiration, hold the breath, and measure again.

Give some idea of the difference in cubic capacity, which this difference in circumference represents.

D. Models to Illustrate the Principles of Breathing.

NOTE. — Adapted from *Hints for Teachers of Physiology* by Professor Bowditch.

I. THE VERTICAL ENLARGEMENT OF THE THORAX.

Apparatus. A glass bottle without the bottom, or a lamp-chimney. A piece of rubber dam about half an inch larger than the lower part of the chimney. A toy rubber balloon used by small boys, called a "squawker," or another piece of rubber dam about six inches in diameter. A rubber stopper, with two holes in it, to fit the upper end of the chimney. About twelve inches of glass tubing to fit the holes in the stopper. A pinch-cock. Linen thread. Three inches of rubber tubing to fit the glass tubing. A stout rubber band.

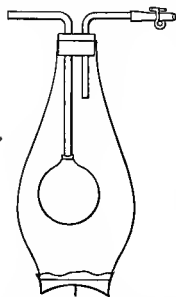


FIG. 7. — A model to show the vertical enlargement of the thorax.

The apparatus should be put together very carefully, as in Fig. 7, to prevent the escape of air.

a. The chimney represents the chest cavity.

b. With an elastic band fasten over the lower end of the chimney a piece of rubber dam to represent the diaphragm.

c. Into the upper end of the chimney fit the rubber stopper containing two pieces of glass tubing, each bent at a right angle. Attach the toy balloon (or the trachea and

lungs may be substituted in the place of the balloon) to the inner end of one piece of the glass tubing. Slip a piece of rubber tubing three inches long over the outer end of the other piece of glass tubing, and put the pinch-cock on the rubber tubing.

d. Partially exhaust the air from the bottle by sucking through the rubber tubing, then close the pinch-cock. This represents the condition in the thorax.

e. Lower and raise the rubber diaphragm. Notice what occurs and explain.

II. THE DORSO-VENTRAL ENLARGEMENT OF THE THORAX.

Apparatus. Six pieces of cardboard or thin wood six inches long and one inch wide. Two light rubber bands. Eight fasteners. Four hooks.

Fasten four parallel pieces of stiff cardboard at right angles to two parallel bars so that they may be moved at the fastenings. Place the hooks at 1, 2, 3, and 4 (Fig. 8) so that a line connecting 1 and 2 shall be at right angles to one connecting 3 and 4. The elastic bands shall be so short as to be put on the stretch when placed over the hooks. The longest piece represents the spinal column. The shortest piece represents the sternum. The three or four pieces of equal length, movable at either end, represent the ribs. The band 1-2, running obliquely downward and forward, represents the external intercostal

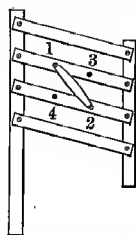


FIG. 8. — A model to show the dorso-ventral enlargement of the thorax.

muscles. The band 3-4, running obliquely downward and backward, represents the internal intercostal muscles.

a. Stretch a band over the hooks 1-2. What change is there in the position of the horizontal pieces of cardboard? What effect does the contraction of the external intercostal muscles have on the ribs and on the chest cavity?

b. Remove the band from hooks 1-2 and stretch it over hooks 3-4. What change is there in the position of the pieces of cardboard? What is the effect of the contraction of the internal intercostal muscles?

III. THE LATERAL ENLARGEMENT OF THE THORAX.

In the body the ribs are curved, instead of being straight as represented in Fig. 8, and as they rise during inspiration, they also bulge outward, thus increasing at the same time the lateral dimension of the chest cavity.

X.

THE ORGANS OF DIGESTION. — THE TEETH AND THE TONGUE.

A. The Parts of a Tooth.

Material. A human incisor tooth.

Specimens of the different kinds of human teeth may be obtained of a dentist.

Study an incisor tooth with reference to the different parts.

Observe :

a. The **crown** is the upper part seen in the mouth.

b. The **root**, or **fang**, is the part embedded in the jaw-bone.

c. The **neck** is a narrow part between the crown and the root, embraced by the edge of the gum.

d. The **hole** is at the tip of the root. What is its use?

e. Sketch a side view.

B. The Structure of a Tooth.

Material. A slide showing a longitudinal section of a human incisor tooth.

Apparatus. A magnifying glass. A compound microscope.

1. Study with a magnifying glass a prepared microscopical slide of a longitudinal section of an incisor tooth.

Observe:

- a.* In the centre is the **pulp cavity**, which is filled during life with a soft pulp containing blood-vessels and nerves.
- b.* The **dentine** is the hard part around the pulp cavity.
- c.* The **enamel** covers the dentine on the crown. How far does it extend?
- d.* The **cement** covers the dentine on the root. How far does it extend?
- e.* Sketch.

2. Study the same slide with the compound microscope, and observe the structure of the different parts.

C. The Different Kinds of Teeth.

Materials. An incisor, a canine, a bicuspid, and a molar tooth.

1. Identify the following kinds of teeth:
 - a.* The **incisor** with a wedge-shaped crown.
 - b.* The **canine** with a pointed crown.
 - c.* The **bicuspid**, or premolar, with a cuboidal crown.
 - d.* The **molar** with an irregular crown.
 - e.* Sketch one tooth of each kind.
2. Compare the parts in the different teeth.
 - a.* How many cusps or points has each?
 - b.* How many fangs has each?
3. Arrange them on the table as they are in the jaw.
4. A dental formula is often used as a short method to indicate the number of teeth. The numerator indicates the number of teeth in one side of the

upper jaw, and the denominator the number in one side of the lower jaw; as, I_2^3 , C_1^1 . I_2^3 indicates that there are two incisor teeth in one side of the upper jaw and three in one side of the lower jaw.

a. Write the formulæ for the premolar and the molar teeth.

b. What are the wisdom teeth?

D. The Teeth of the Lower Animals.

Materials. The teeth of a horse or cow. The teeth of a cat or dog.

1. Study the teeth of an herbivorous animal and compare them with the human teeth.
2. Study the teeth of a carnivorous animal and compare them with both the preceding.

E. The Tongue.

Apparatus. A hand-mirror.

With a hand-mirror examine your own tongue.

Notice:

a. The small papillæ that cover most of the upper surface of the tongue are the **filiform papillæ**.

b. The larger papillæ that are scattered occasionally over the surface are the **fungiform papillæ**.

c. The very large papillæ, or the **circumvallate papillæ**, are situated as far back on the tongue as you can see. How are they arranged?

d. Sketch.

XI.

OTHER ORGANS OF DIGESTION.

The Digestive Organs of the Rabbit.

A. The General Plan of the Body — Preliminary.

Materials. A live rabbit. Chloroform. Cotton batting. Water.

Apparatus. An air-tight jar or box just large enough to hold the rabbit.

Kill the rabbit by placing it in an air-tight box with some cotton batting saturated with chloroform. When ready for dissection, lift the skin of the ventral side and make a cut along the median line from near the base of the tail forward to the breast-bone. Cut through the skin, and also through the body-wall. At the posterior and anterior ends of the slit make cross-cuts extending nearly around to the spinal column on either side and lay back the flaps of the skin.

Notice :

a. The larger cavity at the posterior end of the body is the **abdominal cavity** and contains all the visceral organs.

b. The smaller cavity toward the anterior end of the body is the **thoracic cavity**.

c. The large circular muscle is the **diaphragm** and separates the thoracic and the abdominal cavities.

d. Sketch.

B. The Alimentary Canal.

I. THE TEETH.

Examine the teeth and compare them with the human teeth.

a. How many **incisor** teeth are there?

1. What is peculiar about them?

2. What is the purpose of this?

b. How many **canine** teeth has the rabbit?

c. Find the **premolar** teeth.

d. Are there any **molar** teeth?

e. What is the dental formula of the rabbit?

II. THE MOUTH, OR BUCCAL CAVITY.

Notice its general shape and size.

III. THE PHARYNX, OR THROAT CAVITY.

a. Can you find the **nasal** openings on the dorsal surface?

1. How many are there?

b. Look carefully on the sides for the openings into the **Eustachian** tubes. Pass a bristle along one tube into the middle ear.

c. On the ventral surface of the pharynx look for the opening into the windpipe, — the **glottis**. Which way does the lid, or **epiglottis**, open?

.

d. Find the opening into the gullet, or *œsophagus*. Is it ventral or dorsal to the glottis?

e. Sketch.

IV. THE *ŒSOPHAGUS*.

Trace the tube from its opening in the pharynx to the stomach.

a. Through what cavity does it pass?

b. Through what part of the cavity?

c. Through what muscle does it extend?

d. Is it the same size throughout?

NOTE.—A few minutes may well be spent in identifying and reviewing the lungs, trachea, heart, and main blood-vessels, since the organs are here intact.

V. THE STOMACH.

The *stomach* will be found just beneath the diaphragm.

a. What is its shape and color?

b. What is its position in relation to the surrounding organs?

c. Does the *œsophagus* open into the broad or the narrow end of the stomach?

d. This opening between the *œsophagus* and the stomach is the *cardiac orifice*, and this end of the stomach is the *cardiac end* of the stomach.

1. Is it on the right or the left side of the body?

2. Why is it called the *cardiac end* of the stomach?

e. From which end of the stomach does the small intestine lead? The opening between the intestine and the

stomach is the **pyloric orifice**, and this is the pyloric end of the stomach.

1. On which side of the body is this end of the stomach?
2. What lies between the pyloric end of the stomach and the diaphragm?

VI. THE SMALL INTESTINE.

The **small intestine** extends from the stomach to the large intestine.

- a.* Is it the same size throughout?
- b.* What is its position in relation to the other organs?
- c.* What holds it in position?
- d.* What color is it?

VII. THE LARGE INTESTINE.

The remaining part of the alimentary canal is the **large intestine**. It is composed of three parts — the **cæcum**, the **colon**, and the **rectum**.

a. The smaller intestine opens into the side of the large intestine, leaving one end of the latter free in the body cavity. This free end is the **cæcum**, and is much larger in the rabbit than in man. What color is it?

1. Opening from the end of the **cæcum** is a small tube, the **vermiform appendix**. Inflammation of this part causes **appendicitis**.

b. The **colon** begins at the opening from the small intestine, and extends nearly to the end of the alimentary canal. It is the longest part of the large intestine.

1. What is its position in the abdominal cavity?
2. Is it the same size throughout?
3. What color is it?

c. Near the end of the alimentary canal the colon passes into the rectum.

VIII. THE LIVER.

There are several glands along the alimentary canal that aid in digestion, the largest of which is the liver.

- a. How many lobes has the liver?
- b. Are they all of the same size?
- c. What is their position?

IX. THE GALL BLADDER.

Raise the lobes of the liver and find the small gall bladder. It is often green in color. Look for the common bile duct leading from the liver and gall bladder to the small intestine.

X. THE SPLEEN.

Near the broad end of the stomach find the spleen, an elongated dark-red body held in place by the thin membrane or mesentery.

XI. THE PANCREAS.

Another gland, a pale-red pancreas, lies in the mesentery in a fold of the small intestine. Look for the opening of the pancreatic duct on the inner wall of the intestine about a foot from the pyloric orifice. Pass a probe into the duct.

XII. THE MESENTERY.

Spread out the intestines and notice the mesentery.

- a.* What is its use?
- b.* What do you find in it?
- c.* Has it any connection with the **peritoneum**, or lining of the abdominal cavity?

XIII. THE ENTIRE ALIMENTARY CANAL.

Remove the entire alimentary canal and straighten it out on the table.

- a.* Measure the various parts.
- b.* How do they compare one with another?
- c.* How do they compare with the length of the body cavities?
- d.* Sketch.

C. A Detailed Study of the Different Organs.

Material. A dissected rabbit.

Apparatus. A magnifying glass.

With the scissors make a small cut in the walls of the **oesophagus**, the **stomach**, the small and large intestines. Wash out the contents.

Study:

I. THE WALL OF THE OESOPHAGUS.

- a.* The muscular coat on the outside.
- b.* The mucous lining within.

II. THE WALL OF THE STOMACH.

- a.* The muscular coat on the outside.
- b.* The mucous coat. Look with the magnifying glass for shallow pits over the surface of the mucous lining. These contain the openings of the **gastric glands** that will

be seen later with the compound microscope. In what part of the stomach are they most numerous?

III. THE WALL OF THE SMALL INTESTINE.

- a.* The muscular coat.
- b.* The mucous lining.
- c.* Look for irregular folds running transversely around the intestine called the *valvulæ conniventes*. What is their use?
- d.* With a magnifying glass examine carefully the surface of the mucous lining, until you find small conical elevations, or *villi*.
- e.* Sketch.

IV. THE WALL OF THE LARGE INTESTINE.

- a.* The muscular coat.
- b.* The mucous lining. What do you find on this? Compare with the small intestine.

D. The Microscopical Structure of the Alimentary Canal.

Materials. Microscopical slides showing cross-sections of the walls of the stomach, the small intestine, the pancreas, and of the liver.

Apparatus. Compound microscope.

I. THE MICROSCOPICAL STRUCTURE OF THE WALL OF THE STOMACH.

Examine with the compound microscope a cross-section of the wall of the pyloric end of the stomach.

Notice:

- a.* The muscular coat.
 1. Which way do the fibres extend?
 2. How thick is the coat compared with the thickness of the entire wall?

b. The mucous coat.

1. How thick is this coat?
2. Do you find the shallow pits on the surface?
3. The long tubes opening on the inner surface are the **gastric glands**.

c. The submucous coat lies between the mucous and the muscular coats. What do you find here?

d. Sketch.

II. THE MICROSCOPICAL STRUCTURE OF THE WALL OF THE SMALL INTESTINE.

Examine with the compound microscope a cross-section of the wall of the small intestine that has been injected.

Notice:

a. The muscular coat.

1. How thick is it?
2. Which way do the fibres extend?

b. The mucous coat.

1. Is it as thick as that of the stomach?
2. Do you find the villi? Notice the blood-vessels in them. The lacteal is the large vessel in the centre of each villus.
3. The tubular glands opening on the inner surface are the **crypts of Lieberkühn**.

c. The submucous coat is just beneath the mucous coat. What does this contain?

d. Sketch.

III. THE MICROSCOPICAL STRUCTURE OF THE PANCREAS.

Examine a cross-section of pancreas.

Observe :

a. The arrangement of the **cells** in circular groups. Each group is a cross-section of an **alveolus**, or tube formed by secreting cells.

b. A small opening, or **duct**, is in the centre of each alveolus, but is hardly visible, being filled by spindle-shaped cells.

c. The alveoli are grouped around larger ducts to form **lobules**, which in turn unite to form the lobes of the pancreas.

d. The lobes, the lobules, and the alveoli are bound together by **connective tissue** carrying the blood-vessels.

e. Sketch and label the various parts.

IV. THE MICROSCOPICAL STRUCTURE OF THE LIVER.

Examine in the same way a cross-section of liver.

Observe :

a. The **hepatic cells** of which the liver is everywhere composed. What parts of the cell can you distinguish? How are they arranged?

b. An **hepatic veinlet** is seen in section in the centre of each group or lobule of hepatic cells. Whither does this blood-vessel lead?

c. Branches of the **portal vein** and **hepatic artery** may be traced in the connective tissue between the lobules.

d. The **bile ducts** are small tubes lined with a single layer of cuboidal cells. What is their use?

e. Sketch.

XII.

FOODS.

All foods consist primarily of water, proteids or protein, fats, carbohydrates, and inorganic salts.

A. Water in Foods.

Materials. Potato. Carrot. Turnip. Cabbage. Apple.

Apparatus. Oven. Standard Fairbanks scales.

I. WATER IN POTATOES.

Experiment:

1. Wash a potato thoroughly and dry it.
2. Weigh it.
3. Heat it in an oven or on the radiator until completely dried. Take care not to burn it.
4. Weigh it again.
5. Calculate the per cent of water in potato.

II. WATER IN OTHER VEGETABLES.

Experiment:

1. In the same way examine carrot, turnip, onion, cabbage, or apple, and calculate the per cent of water.
2. Compare your result with a list of food compositions.

B. Carbohydrates in Foods — Starch.**I. THE IODINE TEST FOR STARCH.**

Materials. A few grains of starch. An aqueous or alcoholic solution of iodine. Water.

Apparatus. A test-tube. Bunsen burner.

Experiment:

1. Thoroughly mix the starch with about 10 c.c. of cold water.
2. Dilute, boil, and cool.
3. Add a few c.c. of iodine solution.
4. Dilute again if the color is very dark. Boil and cool.

II. STARCH IN POTATO.

Materials. Potato. Water. Iodine solution (either aqueous or alcoholic).

Apparatus. Evaporating dish. Knife. Bunsen burner.

Experiment:

1. Wash thoroughly a potato and peel it.
2. Grate or slice it very thin and wash in an evaporating dish.
3. Collect the white sediment.
4. Boil some of this with water.
5. Test for starch with iodine.

III. THE STRUCTURE OF THE STARCH GRAINS OF THE POTATO.

Materials. A few starch grains just washed from a potato.

Apparatus. Glass slide. Cover-glass. Compound microscope.

Mount a drop of water containing a few grains of starch and examine with the compound microscope.

Observe :

- a.* The shape of the grains.
- b.* Their concentric structure.
- c.* The **hilum** or centre of the curves.
- d.* Sketch.

Run a drop of iodine solution under the cover-glass and notice the change in the grains of starch.

IV. STARCH IN OTHER FOODS.

Materials. Beans. Peas. Oatmeal. Tapioca. Farina. Rice. Cornstarch. Sago. Barley. Indian meal. Wheat flour. Rye. Crackers. Bread. Iodine solution.

Apparatus. Test-tubes. Test-tube rack. Filter-paper. Funnel. Evaporating dish. Bunsen burner.

Experiment :

Examine for starch one of the following :

Beans, peas, oatmeal, tapioca, farina, rice, cornstarch, sago, barley, Indian meal, wheat flour, rye, crackers, and bread.

1. Make a paste by grinding and mixing with cold water.
2. Add hot water and thoroughly mix.
3. Filter when necessary.
4. Test the filtrate for starch with the iodine test.

Carbohydrates in Foods — The Sugars.

V. TEST FOR DEXTROSE, GRAPE SUGAR — FEHLING'S SOLUTION.

Materials. 15 c.c. of Fehling's solution, which is a solution of alkaline potassio-tartrate of copper $K_2Cu(C_4H_4O_6)_2$. Three grapes. Water.

Apparatus. Test-tubes. Bunsen burner. Mortar and pestle. Funnel and filter-paper.

Experiment :

1. Boil 15 c.c. of Fehling's solution in a test-tube.
If no yellow color appears, the solution is in good condition.
2. Thoroughly mix with water in a mortar three or four grapes.
3. Filter.
4. Test the filtrate for a reducing sugar as follows :
5. Add 1 c.c. of the filtrate to the Fehling's solution and boil. What color is the precipitate cuprous oxid, Cu_2O ? The sugar acts as a reducing agent and changes the cupric salt to a cuprous salt. This is characteristic of dextrose, but there are other sugars, as maltose and lactose (milk-sugar), that reduce metallic salts, although in a less degree.

VI. TEST FOR DEXTROSE — BARFOED'S SOLUTION.

Materials. 15 c.c. of Barfoed's solution, which is a solution of acetate of copper in water acidulated with acetic acid. 5 c.c. of a solution of dextrose.

Apparatus. Test-tubes. Bunsen burner.

Experiment:

To the Barfoed's solution in a test-tube add the solution of dextrose and boil. What color is the precipitate? What is it? This test distinguishes dextrose from lactose, maltose, and cane-sugar, which do not reduce Barfoed's solution when boiled with it for a short time.

VII. SACCHAROSE, CANE-SUGAR, AND FEHLING'S SOLUTION.

Materials. A few grains of cane-sugar. 15 c.c. of Fehling's solution. Water.

Apparatus. Test-tubes. Bunsen burner.

Experiment:

1. Boil the Fehling's solution in a test-tube.
2. Dissolve the sugar in 10 c.c. of water.
3. Add the solution of sugar to the Fehling's solution and boil. What happens? Does saccharose reduce Fehling's solution?

VIII. THE ACTION OF HYDROCHLORIC ACID UPON SACCHAROSE, CANE-SUGAR.

Materials. 100 c.c. of a strong solution of cane-sugar. 10 c.c. of strong hydrochloric acid. 15 c.c. of Fehling's solution.

Apparatus. A glass flask. Bunsen burner. Ring-stand. Wire gauze.

Experiment:

1. To the solution of cane-sugar in the flask add the hydrochloric acid.
2. Boil one hour or more and cool.

Caution. Never add hot caustic soda or potash to an acid.

3. Test 5 c.c. of the boiled solution for a reducing sugar.

IX. THE ACTION OF HYDROCHLORIC ACID UPON STARCH.

Materials. A few grains of starch. 2 c.c. of hydrochloric acid. 15 c.c. of Fehling's solution. Water.

Apparatus. Test-tubes. Bunsen burner.

Experiment:

1. Mix the starch with 5 c.c. of water.
2. Add the hydrochloric acid. Boil and cool.
3. Add the Fehling's solution and boil. What occurs? Into what has some of the starch been changed?

X. EXAMINE FOODS FOR DEXTROSE.

Examine maple sugar, syrup, molasses, dates, and prunes for dextrose.

XI. THE TASTE OF THE SUGARS.

Taste a small amount of dextrose, saccharose, and lactose and determine which is the sweetest.

C. Proteids in Foods.

I. GENERAL TESTS FOR PROTEIDS.

Egg-albumin, or the white of an egg, is a proteid. Try the following tests for proteids upon some raw white of egg diluted with water.

a. First test: Xanthoproteic Reaction.

Materials. 5 c.c. of egg-albumin diluted with water. 5 c.c. of concentrated nitric acid. 5 c.c. of ammonium hydrate.

Apparatus. Test-tubes. Test-tube rack. Bunsen burner.

Experiment:

Add the nitric acid to the proteid and heat. What

happens? Cool under the faucet and add the ammonium hydrate. What happens? The color is characteristic.

b. Second test: Piotrowski's Reaction.

Materials. 5 c.c. of proteid solution. 10 c.c. of a concentrated solution of sodium hydrate. 2-3 drops of a one per cent solution of cupric sulphate.

Apparatus. Test-tubes. Test-tube rack. Bunsen burner.

Experiment:

To the proteid solution add the sodium hydrate and then the cupric sulphate. What color is obtained? Boil. What change is there in the color? This test detects the smallest traces of all proteids.

c. Third test.

Materials. 5 c.c. of proteid solution. 5 c.c. of acetic acid. 3-4 drops of potassium ferrocyanide.

Apparatus. Test-tubes.

Experiment:

To the proteid solution add the acetic acid and then the ferrocyanide. What occurs?

II. EXAMINE MILK FOR PROTEIDS.

Materials. 10 c.c. of milk. 40 c.c. of water. 5 c.c. of acetic acid or vinegar. 10 c.c. of lime-water. 10 c.c. of a concentrated solution of sodium hydrate. 2-3 drops of a dilute solution of cupric sulphate.

Apparatus. Test-tubes. Test-tube rack. Bunsen burner. Filter-paper. Funnel.

Experiment:

1. Dilute the milk with the water and add the acetic acid. What happens? This precipitate is the proteid, casein.

2. Filter. What is the filtrate?
3. Add a little of the casein to water and shake.
Is the casein soluble in water?
4. Add a little of the casein to lime-water and shake. Is it soluble?
5. Test milk by the second method above for proteid.
6. Boil some milk. Does the casein coagulate?
Compare this result with the action of heat upon egg-albumin.

III. TEST CHEESE FOR PROTEIDS.

Materials. A small piece of cheese. 25 c.c. of lime-water. 10 c.c. of sodium hydrate (concentrated). 2 or 3 drops of cupric sulphate.

Apparatus. Test-tube. Filter-paper. Funnel. Bunsen burner. Evaporating dish.

Experiment :

1. Thoroughly mix a small piece of cheese with about 25 c.c. of lime-water.
2. Filter. Is the proteid in the precipitate or filtrate?
3. Test for proteid by the second test above.
4. From what is cheese made?
5. What proteid is in milk?
6. What proteid is in cheese?

IV. EXAMINE MUSCLE FOR PROTEIDS.

Materials. A piece of lean beef. 25 c.c. of 10 per cent solution of ammonium chloride. Lime-water. 20 c.c. of a concentrated solution of sodium hydrate. 4-6 drops of cupric sulphate. Alcohol, 75 per cent solution.

Apparatus. Evaporating dish. Filter-paper. Test-tube. Bunsen burner. Funnel.

Experiment :

1. Thoroughly wash and mince a piece of lean beef.
2. Save the washings and test for proteid.
3. Mix the meat with ammonium chloride. The ammonium chloride dissolves the proteid, myosin, in the muscle.
4. Filter. Is the myosin in the precipitate or filtrate?
5. Test part of the filtrate for proteids by the second test.
6. Add alcohol to part of the filtrate until a precipitate is formed. Myosin is insoluble in alcohol. What is the precipitate?
7. Heat in a test-tube some of the solution of myosin. Notice what change takes place, and compare the result with the effect of heat upon egg-albumin and casein.

D. Fats in Foods.**I. AN EMULSION.**

Materials. Water. 5 c.c. of olive oil. 2 small pieces of butter.
An egg.

Apparatus. Test-tubes. Evaporating dish. Bunsen burner.

Experiment :

1. Add 2 c.c. of oil to about 10 c.c. of water. What occurs? Why?
2. Add a piece of butter to 10 c.c. of water. What occurs? Why? Why does cream rise?
3. Repeat experiment 2 with melted butter.

4. Melt the butter and add it to the white of an egg. Beat them together. Add the water and beat again. Does the butter and water mix? Why? This is an emulsion. Of what advantage is it in digestion?

II. THE EMULSION OF FAT IN MILK.

Materials. 1-2 c.c. of milk.

Apparatus. A glass slide. A cover-glass. Compound microscope.

Mount a drop of milk and examine under the microscope.

Notice :

a. The fat globules.

b. The liquid.

c. Sketch.

d. In what form is the fatty portion of the milk? Is this an advantage or a disadvantage in digestion? Why? Compare the results obtained from c. II, and infer what it is that renders milk so valuable as a food.

III. THE EXTRACTION OF FAT FROM FOODS.

Materials. Indian meal. Whole wheat flour. Common flour. Benzine.

Apparatus. Evaporating dish. Filter-paper. Funnel.

Extract the fat from the Indian meal, whole wheat flour, and common flour.

Experiment:

1. Mix the Indian meal with benzine or ether.
2. Filter and allow a drop of the filtrate to evaporate on a piece of clean glass. What is left? Prove that this contains fat. What, then, is one of the food constituents of Indian meal?
3. Test in the same way the whole wheat and common flour. Which contains the most fat?

XIII.

DIGESTION.

The Effect of the Digestive Fluids on Foods.

A. The Saliva.

I. THE MICROSCOPICAL EXAMINATION OF SALIVA.

Material. Saliva.

Apparatus. A test-tube. A glass slide and cover-glass. A compound microscope.

Collect half a test-tube of saliva. Mount a drop on the glass slide and examine with the compound microscope.

Notice :

- a.* The epithelial cells. Where did they come from?
- b.* Possibly, débris of food.
- c.* Forms of bacteria.

II. THE EFFECT OF SALIVA ON STARCH.

Materials. Potato starch. Saliva.

Apparatus. Warm water-bath, or one made of a large beaker. A Bunsen burner. A ring-stand. A piece of wire gauze six inches square. A thermometer. Test-tubes and rack.

Prepare a warm water-bath by filling the beaker to a depth of three or four inches with water, and placing it on the wire gauze on the ring-stand, over the Bunsen burner. Stand the thermometer in the water and keep it at a temperature of 42° C.

Experiment:

1. Make a dilute starch paste of pure potato starch and boil for a few minutes. One grain of starch to 200 c.c. of water is sufficient.
2. Dilute 5 c.c. of saliva with 25 c.c. of water.
3. Place one of the following solutions in each of three test-tubes:
 - (1) 20 c.c. of starch paste.
 - (2) 20 c.c. of diluted saliva.
 - (3) 5 c.c. of saliva and 15 c.c. of starch paste.
4. Place in the warm bath for ten minutes and then test each for maltose. What is the effect of saliva on starch? Why was the mixture kept at a temperature of 42° C.?

B. The Gastric Juice.**I. THE PREPARATION OF ARTIFICIAL GASTRIC JUICE.**

Materials. $\frac{1}{2}$ a gram of pepsin. 2 c.c. of strong hydrochloric acid. 50 c.c. of water.

Apparatus. A small beaker. A warm water-bath and thermometer.

The essential constituents of gastric juice are hydrochloric acid, pepsin, and rennin. As far as we know, the action of rennin is confined to the curdling of milk, so that a solution of pepsin, slightly acidulated with hydrochloric acid, represents the action of the normal gastric juice on proteids.

Experiment:

Mix the water, the acid, and the pepsin in the beaker and place this in a warm water-bath. Insert the ther-

mometer and keep the temperature at 100° F. or 42° C. The body temperature is about 38° C.

II. THE ACTION OF GASTRIC JUICE ON PROTEIDS.

Materials. Egg-albumin. Artificial gastric juice. Water.

Apparatus. Evaporating dish. Glass stirring rod. Test-tubes and rack. Warm water-bath and thermometer.

Caution. Label all of your test-tubes.

Experiment:

1. (Preliminary) Heat some water in an evaporating dish. Into this drop a little well-shaken egg-albumin and stir constantly.
2. Add a small piece of the coagulated albumin, not minced, to 10 c.c. of gastric juice. Keep it cool and still.
3. Add a small piece of the egg-albumin, minced, to 10 c.c. of gastric juice. Place it in the water-bath but keep it still.
4. Add the same amount of minced egg-albumin to 10 c.c. of gastric juice. Keep at 42° C., but shake often to imitate the action of the stomach. Compare the three results at the end of two hours. What three conditions aid digestion?

III. ARE BOTH ACID AND PEPSIN NECESSARY TO DIGESTION?

Materials. Coagulated egg-albumin. Water. Dilute hydrochloric acid. Pepsin.

Apparatus. Test-tubes. Warm water-bath.

Place a small piece of coagulated egg-albumin in each of four test-tubes.

Experiment:

1. To the first test-tube add 10 c.c. of water.
2. To the second test-tube add 10 c.c. of dilute hydrochloric acid.
3. To the third test-tube add 10 c.c. of pepsin and water.
4. To the fourth test-tube add 10 c.c. of pepsin and dilute hydrochloric acid.
5. Place all the test-tubes in the warm bath and notice the results at the end of one or two hours.

IV. THE ACTION OF GASTRIC JUICE ON MILK.

Materials. 10 c.c. of milk. 10 c.c. of water. A few grains of pepsin. Rennet.

Apparatus. Test-tubes. Warm water-bath.

When the milk reaches the stomach it is first acted upon by the rennin and then by the pepsin and hydrochloric acid.

Experiment:

1. The action of the rennin. (Rennin is the essential element of rennet, which is obtained from the fourth stomach of the calf.) Add 4 or 5 drops of rennet to the milk in a test-tube, and allow it to stand a few minutes in the warm water-bath. What is the curd and the whey? What is the action of rennin on milk?
2. The action of pepsin. Mix the curdled milk, the pepsin, and water in a test-tube and place it in the warm water-bath. Look at it every fifteen minutes. What takes place?

3. The action of pepsin and hydrochloric acid. To part of the above mixture add a few drops of hydrochloric acid and keep it in the water-bath. Compare the two at the end of two or three hours. Have both the proteid and the fat constituents been acted upon? What shows this? What is the action of gastric juice on milk?

C. The Pancreatic Juice.

I. THE PREPARATION OF ARTIFICIAL PANCREATIC JUICE.

Materials. 100 c.c. of water. 15 grains of sodium carbonate, baking soda. 5 grains of pancreatin.

Apparatus. A small beaker. A water-bath and thermometer.

The essential elements of pancreatic juice are trypsin, amyllopsin, steapsin, and rennin. Trypsin acts upon the proteids, amyllopsin upon the carbohydrates, and steapsin upon the fats. The action of rennin is to coagulate whatever casein may have escaped coagulation by the gastric juice.

Experiment:

In the small beaker mix the pancreatin with the aqueous solution of sodium carbonate. Place in the water-bath and keep it at 42° C.

II. THE ACTION OF PANCREATIC JUICE ON FATS.

Pancreatic juice acts upon fats, starch, and proteids.

Materials. 5 c.c. of olive oil. A tablespoonful of flour. 5 c.c. of melted butter. 20 c.c. of artificial pancreatic juice.

Apparatus. Evaporating dish. Test-tubes and rack. Warm water-bath.

Experiment :

1. Recall the experiments on fats in food.
2. Make an emulsion with olive oil, flour, and water.
3. To 10 c.c. of warm artificial pancreatic juice add 1 c.c. of olive oil. Shake.
4. To 10 c.c. of warm pancreatic juice add 1 c.c. of melted butter. Shake and allow to stand in the warm water-bath. What is the action of pancreatic juice on fats as far as you can judge from these experiments? Compare with results in B. IV.

III. THE ACTION OF PANCREATIC JUICE ON PROTEIDS.

Materials. 15 c.c. of artificial pancreatic juice. A piece of raw lean beef cut in small pieces.

Apparatus. Test-tube. Warm water-bath.

Experiment :

Into 15 c.c. of pancreatic juice drop the small pieces of beef. Place the test-tube in the warm water-bath and watch from time to time. Compare this action with that of the gastric juice.

IV. THE ACTION OF PANCREATIC JUICE ON MILK.

Materials. 40 c.c. of milk. 20 c.c. of warm pancreatic juice. 30 c.c. of acetic acid, 5 c.c. of hydrochloric acid.

Apparatus. Test-tubes. Warm water-bath.

Experiment :

1. To 20 c.c. of milk add 5 c.c. of hydrochloric acid and shake. What is the precipitate? Filter

and wash the precipitate two or three times. Add some of this coagulated casein to 10 c.c. of pancreatic juice and place in the warm water-bath. Normally, what curdles the milk? What is the effect of the pancreatic juice on the curd?

2. Mix 20 c.c. of the milk and 10 c.c. of pancreatic juice. Place in the warm bath and watch for results. After an hour what has occurred? The precipitate is casein. Is it in fine particles or in solid clots?
3. This experiment is to be performed after the milk has been digested in experiment 2 for an hour. Place in one test-tube 10 c.c. of fresh milk and in another 10 c.c. of the milk of experiment 2. Add to each the same amount, about 15 c.c. of acetic acid or vinegar. In which is the clot more firm? Milk is often treated with pancreatin or "peptonized" for children and invalids. Why?

D. Absorption of the Soluble Products of Digestion.

After the food has been acted upon by the various digestive fluids of the alimentary canal, it is ready to supply nourishment to the body. The products of digestion, then, must in some way pass through the walls of the alimentary canal and pass into the blood, in order to reach the various organs of the body. Just how these substances are able to pass through the walls of the intestine has long been a question among physiologists. It is

now thought that the epithelial membrane, composed of a single layer of cells, takes an active part in the absorption of the soluble products of digestion. The laws that control living cells are probably different from those of 'imbibition' and 'osmosis' with a dead membrane. But as these physical laws may aid in absorption they should not be disregarded.

I. THE EPITHELIAL CELLS.

Review the microscopical slide showing a section of the wall of the small intestine. Recall particularly the epithelial cells, their shape, size, arrangement, and the number of layers.

II. DIFFUSION.

Materials. 20 c.c. of water. 10 c.c. of oil. 5 c.c. of ink.

Apparatus. Test-tubes.

Experiment :

1. Shake 10 c.c. of water and 10 c.c. of oil together.
Do they mix or diffuse?
2. Shake the water and ink. Do they mix? What is meant by diffusion? Why do the water and ink diffuse while the water and oil do not?

III. OSMOSIS.

Materials. Two eggs. A cup of vinegar. Dextrose.

Apparatus. A large beaker. Tape-measure.

Experiment :

1. Measure the circumference of an egg around the short axis and around the long axis, and make a record of the measurements.

2. Place the egg in dilute acetic acid or vinegar, and leave it a day or two until all the lime in the shell has been dissolved.
3. Wash and place it in a solution of dextrose.
4. After a day or two measure the circumference in the same places as before and compare these measurements with those first taken. What does the difference show?
5. Test the second egg for dextrose.
6. Test the egg that has been in the dextrose solution for dextrose.
7. What has taken place in the first egg?

IV. IMBIBITION.

A. Capillary Imbibition.

Materials. Any colored solution, as red ink. Blotting-paper.

Apparatus. Glass tubing of different sizes.

Experiment :

1. Place a few pieces of glass tubing of different sizes in a glass of red ink and note the result.
2. Suspend a strip of filter-paper or blotting-paper so that one end dips in the red ink. Leave for some time. What happens? Why?

B. Molecular Imbibition.

Materials. Glue. Water.

Apparatus. A small beaker.

Experiment :

1. Soak a piece of glue in cold water for about half an hour. Compare this with a piece of the dry glue and explain the difference.

2. Put a rubber cot on a finger and allow it to remain for some time. Explain the result.
 3. Explain the condition of the hands after they have been in warm water for some time.
 4. Explain the uncomfortable feeling produced by wearing rubber shoes or boots for a long time.
- .

XIV.

THE KIDNEYS.

A. The Kidney of a Sheep.

Material. A kidney of a sheep. This may be obtained at any market.

Cut away most of the fat surrounding the kidney and any other tissues that may be attached, but leave the ureter and blood-vessels untouched.

I. THE EXTERNAL PARTS.

Notice :

- a.* The shape of the kidney.
- b.* The size.
- c.* The tube or **ureter** leading from the kidney.
- d.* The **blood-vessels**.
- e.* The **fat**. What is its use?
- f.* The thin **skin** on the outside.
- g.* The **hilus**, or deep fissure on the inner border. Where does it lead?
- h.* Sketch.

II. THE INTERNAL PARTS.

Cut the kidney in halves longitudinally, making the cut through the hilum and parallel to the broad side of the kidney.

Notice :

- a.* The **pelvis** is the widened end of the ureter.
- b.* The cups, or **calices**, are the smaller cavities that unite to form the pelvis.
- c.* The **cortical** portion is the outer part of the wall of the kidney. What is its color and structure?
- d.* The **medullary** portion is within the cortex. It is divided into separate pyramidal portions, called the pyramids of Malpighi. How does it compare in color and structure with the cortex?
- e.* Sketch.

III. THE MICROSCOPICAL STRUCTURE OF THE KIDNEY.

Material. A prepared radial section of injected kidney.

Apparatus. A compound microscope.

Examine under a low power and determine :

- a.* The **uriniferous tubules**, or small tubes, compose the larger part of the medullary and cortical portions. Each tube is very complicated and is composed of straight and convoluted parts. It arises in a Malpighian body (see *b*) and after passing through the cortical and medullary portions, finally opens at the apex of a pyramid.
- b.* The **Malpighian bodies** are small spherical bodies in the cortical portion of the kidney. Each one is composed of a network of capillary blood-vessels, surrounded by a thin membrane which narrows to form the beginning of a tubule. The fluid is secreted in the capsule and in a part of the tubules.

XV.

THE SKIN AND BODILY TEMPERATURE.

A. The Gross Structure of the Skin.

I. THE SKIN ON THE HAND.

Apparatus. A magnifying glass.

Examine with a magnifying glass the skin of the palm of the hand.

Notice :

a. The larger furrows, or **creases**. What is their cause?

b. The smaller ridges, or **papillæ**, and the small furrows.
How are they arranged?

c. The small **openings**. These are the openings of the perspiratory, or sweat, glands. How are they arranged?

d. Sketch.

II. THE TWO LAYERS OF THE SKIN.

Apparatus. A sewing needle.

Carefully insert a needle under the outer skin of your finger.

Notice :

a. The two layers of the skin.

b. The outer, dead skin, or **epidermis**.

1. What is its color?

2. Has it blood-vessels or nerves?

c. The inner, true skin, or **dermis**. Has it blood-vessels or nerves?

III. A BLISTER.

When you have a water-blister, insert a needle under the outer skin and find the liquid that collects between the two layers of the skin. Whence does this liquid come? Why does it not exude through the pores of the sweat glands?

IV. ATTACHMENT OF THE SKIN.

Try to lift the skin up away from the underlying tissues in the following places: back of the hand, cheek, forehead, neck, palm of hand, and fingers. What differences in the mode of the attachment in the different places? Why should the skin be so firmly attached to the palms and the fingers?

B. Finger-Prints.

Material. Printer's ink and paper.

Spread a film of thin printer's ink on a piece of paper, glass, or a stamping pad. Place the under surface of the last joint of a finger on the ink and then on a piece of clean paper. Study the print and find the arrangement of the small ridges.

a. Are they in an arch, a loop, or a whorl? What is their use?

b. Make a print of all your fingers and thumbs and compare the results with those of others.

C. The Microscopical Structure of the Skin.

Material. A microscopical slide showing a cross-section of the skin of the head.

Apparatus. A compound microscope.

With the compound microscope examine a prepared slide showing a cross-section of the skin of the head, and find as many as possible of the following parts.

Notice :

a. The epidermis.

1. Its thickness.

2. The three layers of cells.

(1) The outer layer of elongated **horny cells**.

In which direction are they elongated?
Have they any nuclei? What is their relation to dandruff?

(2) The second layer of **rounded cells**.

(3) The third layer of **columnar cells**. In which direction are these cells elongated? Have they any nuclei? Compare with the outer layer and determine the relative amount of life in the two layers. Inferences.

b. The dermis.

1. Its thickness.

2. Its structure.

3. The **hair**.

(1) The root of the hair is the part embedded in the skin.

- (2) The **stem** of the hair is the part outside of the skin. Is this stem solid or hollow? Is it one piece or made up of parts?
 - (3) The **follicle** is the depression in the skin that contains the root. What relation do the walls of the follicle bear to the dermis and epidermis?
 - (4) A modified **papilla** is at the base of the follicle over which the root of the hair fits.
4. The **sebaceous**, or oil, glands.
- (1) Their shape and size.
 - (2). Where do their ducts open?
5. The **perspiratory**, or sweat, glands are the tubular glands.

Find:

- (1) The **body** of the gland. What is its position, shape, size, and structure.
- (2) The gland duct. Follow its course through the epidermis.

D. The Temperature of the Body.

I. THE NORMAL TEMPERATURE.

Apparatus. A physician's thermometer.

Place a physician's thermometer under the tongue in the mouth. Close the lips, hold the thermometer there for five minutes, and then read the temperature.

II. VARIATIONS IN THE TEMPERATURE.

Apparatus. A physician's thermometer.

Take the temperature at different times, when very warm and when cold.

III. THE REGULATION OF THE TEMPERATURE.

Material. Ether or alcohol.

Pour a few drops of ether or alcohol on the hand. How does it feel? Why? How do a dog and a cat cool off? How does a person?

XVI.

THE NERVOUS SYSTEM.

The Brain.

The nervous tissues of the body may be divided into several parts; the brain, the spinal cord, the nerves, the ganglia, and the sympathetic nerves and ganglia.

A. The Brain of a Sheep.

Materials. The head of a sheep. Cotton batting. Potassium bichromate. Formalin or formaldehyde. A human brain if possible.

Apparatus. A meat-saw. Bone forceps. Glass jar.

The head of a sheep, a rabbit, or of some other vertebrate may be obtained and the brain be taken from it. In order to obtain the brain in good condition the roof of the skull must be removed. With a meat-saw, cut across the front of the skull just back of the eyes, and then saw, backward along either side of the head, just above the ears to the opening in the skull where the spinal cord joins the brain. Carefully remove the large, nearly triangular piece of bone. With the handle of a scalpel, slowly free the brain with its coverings from the skull. Take care not to cut the roots of the cranial nerves close to the brain, but preserve them as long as possible. Wrap the brain in a piece of cotton batting to prevent its weight

from flattening it against the side of the jar while soft, and immerse it in the following liquid to harden.

Potassium bichromate	10 grams.
Formalin or formaldehyde 40 per cent . . .	15-20 c.c.
Water	500 c.c.

Allow it to remain in this liquid two weeks, and then remove and wash it in running water for two or three hours. If it is not sufficiently hard, let it stand overnight in a mixture of 350 c.c. of 5 per cent formalin and 150 c.c. of 95 per cent alcohol. If a fresh brain be placed in this latter mixture, it will harden throughout, with no appreciable shrinkage, to the consistency of India rubber within thirty-six hours, but there will be no differentiation of white and gray matter.

The potassium bichromate colors the cellular (gray) tissue, but has no effect upon the fibrous (white) tissue, while alcohol bleaches both tissues.

I. THE BRAIN AS A WHOLE.

a. What is its position, size, and shape?

b. The surfaces of the brain.

1. The dorsal surface is the upper or more rounded surface.
2. The ventral surface is the lower or flatter surface.
3. The anterior end is more rounded than the posterior.

II. THE COVERINGS OF THE BRAIN.

a. The *dura mater* is the thick outer covering.

1. Is it attached to the brain?
2. Is it close to the brain?

3. What is its relation to the long median fissure and to the fissure between the cerebrum and cerebellum?

4. What is its use?

b. The **pia mater** is the thin inner membrane.

1. What is on this membrane?

2. What is its function?

c. The **arachnoid** is between the two. It is a thin membrane just outside the pia mater, and bridges across the fissures.

III. THE GENERAL PARTS.

Carefully remove the dura mater, but the pia mater may remain on the brain to protect it.

a. The **cerebrum** is the large anterior part of the brain. This is the fore-brain.

b. The **cerebellum** or smaller division may be seen on the dorsal surface posterior to the cerebrum. Trace it around toward the ventral surface.

c. The **pons Varolii** is the band that extends across ventrally from one side of the cerebellum to the other.

d. The **medulla oblongata**, or spinal bulb, is beneath the cerebellum, posterior to the pons Varolii. Push the cerebellum gently forward to find the dorsal surface of the medulla. *b*, *c*, and *d* constitute the hind-brain.

e. The **crura cerebri**, or peduncles of the cerebrum, are on the ventral side, just anterior to the pons Varolii.

1. Where do their nerve fibres come from?

2. Whither do they lead?

f. The **corpora quadrigemina** are situated on the dorsal side. Gently press backward the cerebellum and look forward under the cerebrum for them.

1. How many parts are there?
2. What is their shape?
3. Are they all of the same size? *e* and *f* are in the mid-brain.

g. Sketch larger than life-size a dorsal, a ventral, and a lateral view of the entire brain, showing the exact relation of the parts, and label each.

IV. A DETAILED STUDY OF THE PARTS OF THE BRAIN.

a. The cerebrum, or fore-brain.

1. The two **cerebral hemispheres**, the right and the left.
 - (1) Their general shape.
 - (2) How are they separated?
 - (3) How are they connected?
2. The irregular swellings are called **convolutions**.
 - (1) Is there any definite arrangement? Compare the two sides of the same specimen, and then compare your specimen with another.
3. The **fissures** are the depressions between the convolutions. Locate the principal fissures on each hemisphere.
 - (1) The **median fissure** lies between the two hemispheres.

- (2) The **fissure of Sylvius** is on the lateral surface of the hemisphere. It begins about one third the distance from the anterior to the posterior end and runs upward and backward.
 - (3) The **fissure of Rolando** begins at the median fissure on the dorsal surface of the brain and runs downward and forward in front of the fissure of Sylvius.
 - (4) The **parieto-occipital fissure** also begins at the median fissure, but posterior to the fissure of Rolando, and runs across the hemisphere.
4. Find the lobes resulting from these fissures.
- (1) The **frontal lobe** is at the anterior part of the brain.
 - (2) The **occipital lobe** is at the posterior part.
 - (3) The **parietal lobe** lies between the two along the median line.
 - (4) The **temporal lobe** is on the side below the fissure of Sylvius. How many convolutions are there in each lobe?
5. The **olfactory lobes** are the two small elongated lobes on the ventral surface of the hemispheres at the anterior end.
- b. The hind-brain.
1. The **cerebellum**.
 - (1) Its shape. It consists of a central and two lateral parts.

- (2) Its structure. Are there any convolutions and fissures? Is it divided into hemispheres?
 - (3) Its relative size. Compare with the human brain.
2. The medulla oblongata, or spinal bulb.
- (1) Its shape. Raise the cerebellum, push it gently forward, and remove the thin epithelial covering from the dorsal side of the medulla.
 - (2) The **fourth ventricle** is the chamber in the medulla. What is its shape? Where does it open posteriorly?
 - (3) The diverging **posterior columns**, or **pyramids**, are on either side of the fourth ventricle.
 - (4) The **restiform bodies**, a rounded eminence in each column. Anteriorly find where they pass into the inferior peduncles of the cerebellum.
 - (5) The **superior peduncles** of the cerebellum, one on each side, proceed from the cerebellum and pass beneath the posterior corpus quadrigeminum of the same side.
 - (6) On the under, or ventral, surface of the medulla notice two cords, the **anterior pyramids**. Compare them with the posterior pyramids.
 - (7) The **pons Varolii**. In which direction do its fibres run? Follow its fibres on

each side into the middle peduncles of the cerebellum.

c. The mid-brain.

1. The **optic tracts** are two bundles of fibres coming obliquely forward over the front part of the peduncles and meeting in the centre to form the **optic chiasma**. What is the meaning of this crossing? What relation does it bear to the optic nerves and the sensation of light?
2. The **tuber cinereum** is the small triangular or nearly quadrilateral area at the anterior part of the crura cerebri in the angle of divergence of the optic tracts.
3. The **infundibulum** extends from the tuber cinereum to the pituitary body that may have been torn off in removing the brain from the skull. Notice the cavity in the infundibulum.
4. The **pineal gland** is the small body above the corpora quadrigemina.
5. Sketch the details in your dorsal, ventral, and lateral views of the brain.

B. The Motor and Sense Areas.

The surface of the cerebrum has been partly mapped out into motor and sense regions. These are divided into areas for the muscle-groups belonging to different members of the body; the foot, the arm, etc. The stimulation of a certain part of an area for the arm results in movements of extension, the stimulation of another part of the area results in flexion of the arm. Moreover, each area may

be marked off into centres which control the motion of a smaller group of muscles, as of a part of the arm. The area of the arm would thus be the sum total of centres for the various movements of which all the parts of the arm are capable. The areas affect the movements of the muscles of the opposite side of the body, so that stimulating the area of the arm on the right cerebral cortex will result in movements of the left arm. Locate the main motor and sense areas from the following diagram.

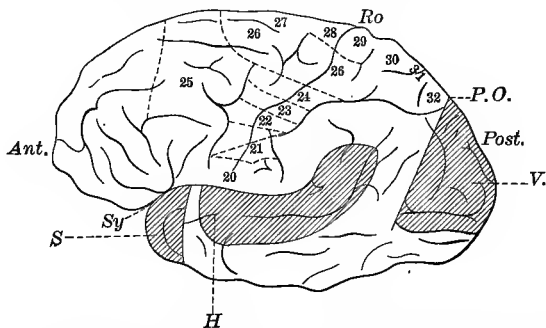


FIG. 9.—The left cerebral hemisphere. *Sy* is the fissure of Sylvius; *Ro*, the fissure of Rolando; *P.O.*, the parieto-occipital fissure; *H*, the area for hearing; *V*, the area for vision; *S*, the area for smelling.

C. The Cranial Nerves.

If the cranial nerves have been severed close to the brain, they should be studied in the interior of the skull. Observe carefully the points of exit of the roots of the nerves.

a. The **olfactory** nerves arise from the olfactory lobes.

b. The **optic** nerves arise from the optic tracts just anterior to the crura cerebri.

c. The **motor oculi**, or motor nerves of the eye, arise from the inner surfaces of the crura cerebri in front of the pons Varolii.

d. The **pathetici** curve around the front edge of the pons; they originate a little posterior to the corpora quadrigemina.

e. The **trigeminals** are large and conspicuous and arise from the sides of the pons.

f. The **abducens** arise just posterior to the pons.

g. The **facial** nerves are seen at the lower edge of the pons, nearly in a line with the fifth pair.

h. The **auditory** nerves are just outside the seventh pair, and cling to the lateral surface of the medulla. The **glosso-pharyngeal**, the **pneumogastric**, the **spinal accessory**, and the **hypoglossal**, each arises by several roots which form a line on the lateral part of the medulla. Consult a drawing of the human brain.

i. Add the nerves to your ventral view of the brain.

D. The Interior of the Brain.

I. A LONGITUDINAL SECTION.

Make a median longitudinal section of the entire brain, taking great care that it is exactly in the median line.

Identify:

a. All the parts that you have seen on the dorsal and ventral surfaces.

b. The **gray matter** constitutes the outer layer, or cortex. Is it composed of cells or fibres? How is it arranged with reference to the fissures? How thick is it?

c. The white substance is in the centre. Is it cellular or fibrous? How is it arranged?

d. The corpus callosum, a flat, thick band of white tissue curved under at either end and situated in the lower part of the cerebral hemispheres.

e. The cavities of the brain, four of which can be easily distinguished.

1. The lateral ventricles are in the right and left cerebral hemispheres. They will be found after cutting the horizontal sections (Fig. 10, *I* and *II*).
2. The third ventricle is dorsal to the optic tracts. (Fig. 10, *III*.)
3. The foramen of Monroe is the passage from the lateral to the third. It is Y-shaped. (Fig. 10, *F.M.*)
4. The fourth ventricle is in the medulla oblongata, and is merely covered by the membranes of the spinal cord. (Fig. 10, *IV*.)
5. The aqueduct of Sylvius leads from the third to the fourth ventricle. (Fig. 10, *A.S.*)

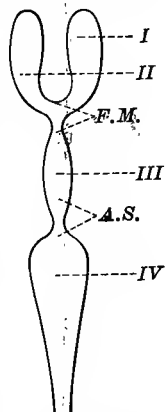


FIG. 10. — A diagram of the ventricles of the brain.

f. Sketch.

II. A HORIZONTAL SECTION.

Cut away the dorsal surface of one hemisphere in thick horizontal sections nearly down to the corpus callosum, noting the arrangement of white and gray matter. Make a shallow, vertical cut into the corpus callosum, parallel with the median fissure and about half an inch from it.

a. Pull up the outer edge of this cut and find a hollow space, the **lateral ventricle**.

b. Cut off its roof and look for the **corpus striatum**, projecting from the floor at the anterior end.

c. Sketch.

III. ANOTHER HORIZONTAL SECTION.

Cut off another section just below the corpus callosum so as to pass through the corpus striatum and the optic thalamus.

Notice :

a. The gray matter around the margin and its relation to the convolutions. What, then, is the purpose of the convolutions?

b. The size and shape of the fissure of Sylvius and the average depth of the fissures between the convolutions.

c. Sketch.

IV. A TRANSVERSE SECTION.

Cut the other hemisphere transversely halfway between the pons and the optic chiasma.

Notice on the cut surface :

a. The shape of the fissure of Sylvius.

b. The gray matter composing the optic thalamus and the corpus striatum.

c. Sketch.

V. THE CEREBELLUM.

Cut the peduncles of the cerebellum and remove it. Cut one half transversely at the centre and determine the relative number and depth of the fissures.

- a.* The **white substance**. How is it arranged?
- b.* The **gray substance**. How thick is it?
- c.* A gray mass, the **corpus dentatum**, is in the centre of the white substance in each lateral lobe.
- d.* Sketch.

VI. THE MEDULLA OBLONGATA.

Make a transverse section of the medulla and note the arrangement of the gray matter within. Make another through the pons, and note the arrangement of the fibres which compose it.

E. The Microscopical Structure of the Brain.

Material. A prepared section of the cerebral cortex of the human brain.

Apparatus. A compound microscope.

Examine a prepared section of the human brain.

THE NERVE CELLS.

Note :

- a.* Their size, shape, and structure.
- b.* Protoplasmic or **branched processes** are called **dendrites**.
- c.* The unbranched process, or **axon**, is continued as the axis cylinder of a nerve fibre. Each nerve cell with all its processes, both dendrites and axons, is called a **neuron**. Do all cells possess both kinds?
- d.* Draw cells showing all these parts.
- e.* How do nerve cells differ from epithelial and muscle cells?

XVII.

THE NERVOUS SYSTEM.

The Spinal Cord.

A. The Gross Structure of the Spinal Cord.

Material. The spinal cord of a calf or some large animal. This may be easily obtained at the large markets. It is only necessary to ask the butcher to save, when he cuts the animal for the market, the long spinal cord that is inside the backbone.

Study the entire cord or a long piece of it.

Notice :

a. The general shape, its length and diameter. Locate the cervical and lumbar swellings in the regions of the neck and the lower part of the back. What causes them?

b. The roots, or attachments, of the spinal nerves.

1. How are they arranged?

2. How near together are they?

c. Sketch.

B. The Microscopical Structure of the Spinal Cord.

Material. A microscopical slide showing a cross-section of a spinal cord.

Apparatus. A magnifying glass. A compound microscope.

I. THE SPINAL CORD SLIGHTLY MAGNIFIED.

Study with a magnifying glass a microscopical slide of a cross-section of a spinal cord.

Notice :

- a.* Its general shape.
- b.* The anterior, **ventral fissure** is the deep indentation on one side.
- c.* The posterior, **dorsal fissure** is on the opposite side.
- d.* The **membranes** around the cord. How many are there?
- e.* The **white substance** is just within the membranes. Distinguish the anterior, lateral, and posterior columns.
- f.* The **gray substance** is within the white substance. What is its shape? Find the anterior and posterior cornua.
- g.* The **canal** is in the centre of the gray substance. What is its size?
- h.* The **cerebro-spinal fluid** was within the canal.
- i.* The **roots** of the nerves. Which roots are they, the anterior or the posterior?
- j.* The **blood-vessels**. What is their relation to the septa or extensions of the pia mater into the cord?
- k.* Sketch.

II. THE SPINAL CORD HIGHLY MAGNIFIED.

Study the section with the high power of the compound microscope.

Notice in the gray substance :

- a.* The nerve cells.
 1. The shape.
 2. The cell **protoplasm**.
 3. The **nucleus**.

4. The nucleolus.

5. The fibres leaving the cells. Is there an axon?
Look for branching fibres.

b. The network of fibres.

c. Compare with the cells of the brain.

d. Sketch.

C. The Structure of Different Parts of the Spinal Cord.

Material. Microscopical slides showing cross-sections of the spinal cord in the cervical, dorsal, and lumbar regions.

Apparatus. A magnifying glass.

Examine the sections of the different regions of the spinal cord.

Notice :

a. Their comparative size and shape. Is the difference due to the gray or white substance? What shows this?

b. The comparative number of cells in the anterior cornua. What does this signify?

c. The comparative amounts of gray and white substance. To what is this due?

d. In the cervical region note the division of the posterior columns into a median and lateral part separated by connective tissue.

e. Make sketches showing typical sections from these three regions.

D. The Spinal Nerves.

Materials. A frog. Chloroform. Formalin, 5 per cent. Cotton batting.

Apparatus. Glass jar. Bell-jar.

Kill a frog and keep it in 5 per cent formalin for three or four days. Cut open the body cavity along the ventral surface, lay aside the intestines, and look for the spinal nerves at the back of the body cavity.

Notice:

a. Their number and arrangement with reference to the vertebræ.

b. Their roots, the anterior and posterior. What is the size and structure of each? On which is the ganglion?

c. Their distribution. To what portions of the body do they extend?

E. Nerve Fibres.

Materials. A frog. Chloroform. Normal salt solution. Cotton batting.

Apparatus. Bell-jar.

Cut off a quarter of an inch of a perfectly fresh nerve, and put it on a slide *without any liquid*. Press one end against the slide, and tease out the other end by passing a needle lengthwise through the fibres. Spread the fibres out like a fan, add a drop of normal salt solution, and cover.

Notice:

a. The relative size and arrangement of the nerve fibres.

b. The connective tissue running amongst and around the fibres.

c. The primitive sheath is a thin, transparent covering on the outside.

d. The medullary sheath, also transparent, is inside the primitive sheath and consists of a fatty substance.

e. The **axon**, or axis cylinder, is in the centre. Add a drop of chloroform and look for this along the centre of the fibres. These are called **medullated** or **white fibres**. Distinguish from them the **non-medullated** or **gray fibres**; where are the latter found?

f. Look for **nuclei** along the nerve fibre.

g. Sketch a single fibre and show all these parts.

F. A Nerve Ganglion.

Material. A prepared section of a nerve ganglion.

Apparatus. A compound microscope.

Examine a section of a nerve ganglion.

Notice:

a. The size and general shape.

b. The outer coat, its thickness and structure.

c. The nerve cells.

1. What is their size and shape?

2. Have they any nucleus?

3. Compare them with those seen in the brain.

d. The fibres. Do any of them join the cells? Are they nerve fibres?

e. Sketch.

G. The Functions of the Spinal Cord. (Reflex Action.)

I. THE KNEE-JERK.

Sit with one knee crossed over the other. With the tips of the fingers strike the crossed knee just below the knee pan. Notice the motion of the foot. Was the action voluntary? Trace the course of the nerve impulse.

II. THE REFLEX ACTION OF THE SPINAL CORD OF A FROG.

Materials. A frog. Chloroform. Hydrochloric acid. Cotton batting.

Apparatus. Bell-jar. Ring-stand.

Etherize a frog, and as soon as it is unconscious sever the brain from the spinal cord by a cut across the back of the neck. With a probe destroy the brain and suspend

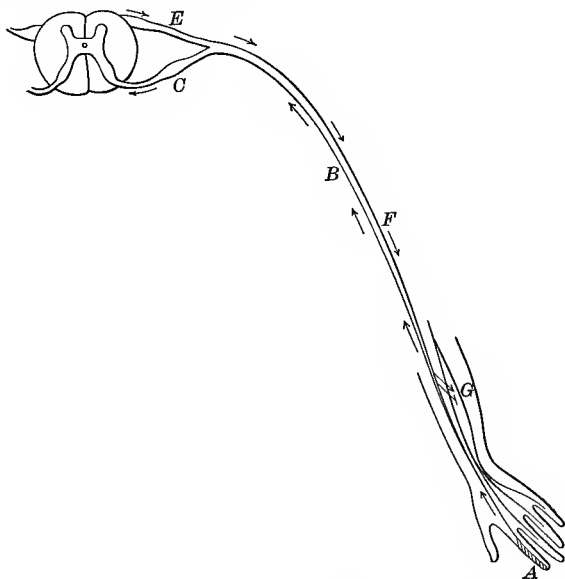


FIG. 11. — A diagram of the reflex action of the spinal cord.

the frog from an iron stand. By pinching with the forceps, gently stimulate one foot of the frog. Give a more vigorous stimulus and compare the result with that previously obtained.

Repeat the same experiment, using a small piece of paper wet in dilute hydrochloric acid as a stimulus. Explain and give the path of the nerve impulse. Destroy the spinal cord by passing a needle down the spinal column and repeat the same experiments.

By a comparison of the results obtained, infer one of the normal functions of the spinal cord in the frog.

H. The Sympathetic System.

Material. A frog that has been in 5 per cent formalin for three or four days. The same frog that was studied for the spinal nerves may be used.

Lay open the body cavity and push aside the intestines and other organs.

I. THE SITUATION OF THE SYMPATHETIC SYSTEM, AND ITS CONNECTION WITH THE CEREBRO-SPINAL SYSTEM.

Just back of the kidneys find a row of small nerve fibres, which run transversely from the spinal nerves to the chain of pigmented, **sympathetic ganglia** close to the dorsal surface and along beside the vertebræ.

II. ITS STRUCTURE.

Notice:

- a. The two rows of sympathetic ganglia.
- b. The nerves connecting the ganglia.
- c. The sympathetic trunks which arise from the ganglia and connecting nerves.
- d. The distribution of its nerves to the digestive, circulatory, and excretory organs.

XVIII.

THE EYE AND VISION.

A. The Eye of an Ox.

Materials. The eye of an ox may be easily obtained at the market. Care should be taken to obtain a fresh specimen. Potassium bichromate, 1 per cent solution.

Apparatus. A small glass jar.

THE PARTS OF THE EYE.

a. The muscles on the outside of the eye.

1. How many do you find?
2. Where are they attached?
3. What is the use of each?

b. Do you find anything else on the outside of the eye?
What is its function?

c. Remove the muscles and fat and find the optic nerve.

1. Is it in the axis of the eye?
2. Can you determine whether your specimen is the right or the left eye?

d. Sketch a front and a side view.

e. The cornea is the transparent coat on the front of the eye.

f. The sclerotic coat is the white or gray opaque coat that is continuous with the cornea. The cornea and the sclerotic coat form the outer covering of the eye.

g. The **conjunctiva** is a thin membrane over the cornea. It is a continuation of the mucous membrane lining the eyelids. In removing the eye, the conjunctiva is cut through where it passes from the eyelids to the sclerotic coat.

h. The **aqueous humor** is found in the anterior chamber of the eye by cutting through the cornea about a quarter of an inch from the junction of the cornea with the sclerotic coat.

i. Find the **iris**.

1. What color is it?
2. What is its shape?
3. Where is it attached?

j. The **pupil**, or opening.

1. How is it formed?
2. What is its shape?
3. How does its shape change?

k. At a short distance posterior to the cornea, cut through the sclerotic coat, being careful not to cut too deeply. The pigmented membrane beneath it is the **choroid** coat. How are the sclerotic and choroid coats connected? Remove a strip of the sclerotic coat one quarter of an inch broad, stretching from the cornea to the optic nerve.

1. What color is its inner surface?
2. The pale fibres of the **ciliary** muscle may be seen in the front part of the choroid close to the cornea. Where do they arise? How far backward do they extend?

l. With forceps, carefully lift the choroid coat about halfway between the optic nerve and the cornea and cut through it. Beneath it the **retina**, a thin membrane, will be seen. The pigment layer of the retina will probably be torn away with the choroid.

m. The **vitreous humor**, which occupies the posterior cavity of the eye, may be seen by tearing away a piece of the retina. What are its characteristics?

n. Hold the eye so that the cornea is underneath. Look through the vitreous humor and see the longitudinal folds of the choroid coat. These are the **ciliary processes**.

o. The **ora serrata** is the uneven line at the level of the commencement of the ciliary processes. The retina ceases along this line.

p. Turn the eye with the iris uppermost and cut away the thin edge of the iris. Find the **lens**. Make a slit in the membrane over the lens and remove it from its **capsule**. Find how far the lens capsule extends. How is it held in place?

q. Study the lens.

1. Its shape, size, and transparency.
2. Are its two faces alike?
3. Lay the lens over some writing and notice the result.
4. Place the lens in a 1 per cent solution of potassium bichromate, and study the structure at the end of a week.

r. The **blind spot** is the place where the optic nerve joins the retina. It may be found by removing the posterior half of the eye.

s. The blood-vessels of the eye may sometimes be seen in the choroid coat radiating from the blind spot after removing the retina.

t. Make a diagram of a median vertical longitudinal section, showing the position of the coats, the lens, the chambers, and the humors of the eye.

u. Label all of the parts that are shown in your sketches.

B. The Human Eye.

Apparatus. A hand-mirror.

Study your own eyes with a hand-mirror.

a. The eyebrows.

1. Their position.
2. The direction of the hair.
3. The thickness and the color of the hair.
4. The hairless place above the bridge of the nose.

b. The eyelids.

1. Their number. Do you see the remnant of another lid at the inner corner?
2. The union of the mucous membrane and the skin on the edge of the eyelid.
3. The openings on the edge of the lower lid.
 - (1) How many are there?
 - (2) What is their use?
4. The larger opening on the slight elevation near the inner angle of the lower lid is the opening into the nasal duct.
5. Do you know any animals that have three eyelids? Do you know any that have no eyelids?

c. The eyelashes.

1. Their position.
2. Their length and shape.

d. The sclerotic coat. What is its color?

e. The iris.

1. What is its color?
2. What is its shape?
3. How does it change with a varying amount of light?
4. What is an albino?

f. The pupil.

1. What is it?
2. What is its shape, size, and color?
3. Compare the pupil with that of the cat, the dog, and other animals.

g. Sketch.

C. The Formation of the Image.

Apparatus. A double convex lens on a stand. A ground glass screen. A candle in a stand. A wooden rod on which the lens, screen, and candle may slide.

I. THE IMAGE ON GLASS.

Arrange the lens, the candle-flame, and the screen so that the image of the flame may fall on the screen. Compare the image of the flame with the flame.

Notice:

- a. The size of the image.
- b. The position of the image.
- c. The distance of the image from the lens.

II. THE IMAGE ON THE RETINA.

Materials. The eye of an albino rabbit. Care should be taken to have it freshly excised, with the cornea still clear, or the experiment will fail. A piece of black paper about six inches square. A candle.

Roll the black paper into the form of a tube, and place the rabbit's eye in it with the cornea directed forwards. Hold the eye in front of a candle-flame, and look for the image of the flame shining through the retina, choroid, and sclerotic coats. Move the flame and watch the image.

D. Accommodation.

Close one eye and hold up both forefingers, the one about six inches, the other about eighteen inches, from the open eye. Look steadily at the nearer finger. Is the image of it clear or indistinct? Do you see clearly the finger farther away? Look steadily at the finger farther away. Is its image distinct? How is the image of the nearer finger? Can you focus on the nearer finger without an effort?

E. Defects in Vision.

Materials. Snellen's cards of test-types including the card for astigmatism.

I. NEARSIGHT AND FARSIGHT.

With the aid of Snellen's test-types, examine your own eyes and determine if they are normal. You should be able to read type of this size **E** at a distance of sixteen feet.

What is nearsightedness, or myopia? What is farsightedness, or hypermetropia? How may each be corrected by the use of glasses?

II. ASTIGMATISM.

Test your own eyes for astigmatism with a card having lines of the same brilliancy radiating from the centre, or with the face of the clock. Astigmatism is present if some of the lines are more distinct or brighter than others.

Astigmatism is usually caused by unequal curvatures of the cornea.

F. Changes in the Iris and the Pupil.

Material. A living cat.

Apparatus. A gas-jet or lamp. A hand-mirror. A piece of cardboard about six inches square.

I. CHANGES IN THE SIZE OF THE PUPIL.

Sit opposite a light and study the pupils of the eyes in a hand-mirror. Place a hand over one eye and notice the diameter of the pupil of the other. Suddenly remove the hand from the eye while watching the pupil of the open eye. What change do you observe?

II. THE RATE OF MOVEMENT OF THE IRIS.

a. The human eye.

Close the left eye, and with the right look through a pin-hole in a card at a white shade of a lighted lamp. Notice the size of the circular visual field, or the amount of space visible at one time. Is it very bright? Open the left eye. What change is there in the visual field? Again close the left eye and note the change in the shape and brilliancy of the visual field.

b. The eye of a cat.

Study the eyes of a cat during sudden changes in the amount of light.

G. Binocular Vision.

While holding a pencil about a foot in front of the eyes, look at a distant object. How does the pencil appear? Close the right eye. What change is there? Close the left eye and open the right.

H. The Blind Spot.

Marriott's experiment:

With the following figure find the blind spot in your own eye. Close the right eye and hold the figure about ten inches in front of the left eye. Look steadily at the



FIG. 12.

cross with the left eye and gradually draw the page toward the eye. Do you find a place where the circle disappears? The image then falls on the entrance of the optic nerve, or the blind spot.

I. The Yellow Spot.

Clark-Maxwell's experiment:

Material. Chrome alum, a strong solution.

Apparatus. A glass bottle with flat sides.

Place a clear, strong solution of chrome alum in a glass bottle with flat sides. Close the eyes for a few minutes and then look through the solution when held between one eye and a white cloud. A rosy spot should be seen in a green field of vision. The pigment in the yellow spot on the retina absorbs the blue-green rays, and so the remaining rays which pass through the alum give a pink color.

J. Irradiation.

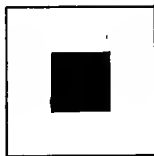


FIG. 13.

a. In Fig. 13 look at the white spot on the black ground, and at the black spot on the white ground. Which spot appears larger?

b. In Fig. 14 look at the four squares, two white and two black. Which looks larger, the white or the black? What is meant by irradiation?

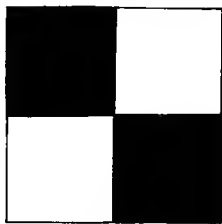


FIG. 14.

K. Imperfect Visual Judgments.

a. Make three round black dots, 1, 2, and 3, of the same size and in the same line, so that 1 and 3 are equidistant from 2. Make several other dots of the same size between 1 and 2.

Which now appear to be farther apart, 1 and 2 or 2 and 3?

b. Make two squares of equal size with very light out-

lines. In one draw parallel horizontal lines, and in the other parallel vertical lines. How do the two squares

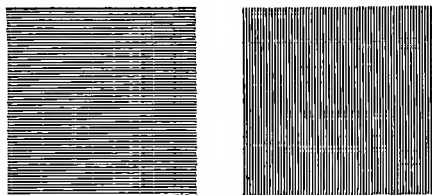


FIG. 15.

now compare in size and shape? Which would make a person look taller, vertical or horizontal lines?

c. Look at the rows of letters, s, and the figures, 8.

S S S S S S S

8 8 8 8 8 8 8

FIG. 16.

Do the upper and the lower halves appear to be of the same size? Invert the page and look again.

d. ZÖLLNER'S LINES. Make six parallel vertical lines. Do they appear parallel? Draw short parallel oblique lines across them, so that those on adjacent verticals

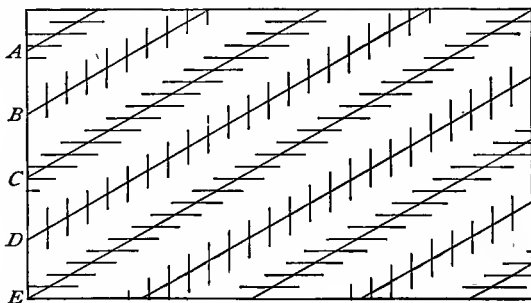


FIG. 17.

shall point in opposite directions. How do the parallel lines now look?

e. Do the long lines appear to be of the same length in Fig. 18? Measure them.

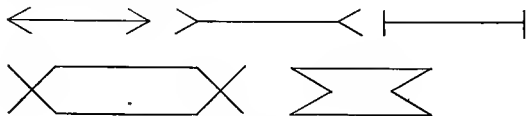


FIG. 18.

L. Color-Blindness.

Material. A large assortment of skeins of worsteds of different colors, shades, and tints. A color-blind person.

Place a large assortment of the shades and tints of different colored worsteds in a good light. Select a light green skein and ask the person to be examined to select all the skeins of the same color whether lighter or darker. A color-blind person will select shades and tints of other colors. Select a bright red skein and ask the person to point out other skeins of the same color. The red-blind person will select green and gray; the green-blind person will select red and gray. Do not ask the person to name colors.

M. Mixing of Color Sensations.

Apparatus. Rotary apparatus for color-disks. The Bradley Color Wheel and Maxwell Disks.

On a rotating disk place a blue and a yellow disk in such proportions as to obtain gray or white when rotated. Why does it not make green? Try different combinations of colors.

N. After-Images.

I. POSITIVE AFTER-IMAGES.

Apparatus. A gas-jet with a white globe.

Rest the eyes by closing them, and then suddenly open the eyes and look for a few seconds at the gas-jet. Now close the eyes again and notice what you see.

II. NEGATIVE AFTER-IMAGES.

Material. Papers of different colors, as red and blue.

Experiment:

1. Look steadily for half a minute or longer at a small white square on a black ground. Then slip a piece of white paper over the whole and notice the image.
2. Look steadily at a bright red square on a black ground, and then slip a piece of white paper over them. What color is the after-image?
3. Obtain the after-images with other colored papers. These images are due to fatigue of the retina and brain. What relation do the colors of the after-images bear to the colors of the paper.

XIX.

THE EAR AND HEARING.

A. The Ear.

Material. The ear of some animal, as a dog, or a large model of the human ear.

Study a large model of the human ear.

Note:

I. THE EXTERNAL EAR.

- a.* The **concha**, or expansion on the outside of the head.
- b.* The passage leading into the head, or **external auditory meatus**.
- c.* The **drum**, or tympanic membrane at the inner end of the passage.

II. THE TYMPANUM, OR MIDDLE EAR.

- a.* The **Eustachian tube** leads from the middle ear to the pharynx. What is its use?
- b.* The three bones of the ear.

- 1. The **malleus**, or hammer, is in contact with the drum.
- 2. The **incus**, or anvil-bone, rests against the malleus.
- 3. The **stapes**, or stirrup-bone, is the innermost bone.

III. THE INTERNAL EAR, OR LABYRINTH.

The Internal Ear, or Labyrinth, is protected by the temporal bone of the skull.

a. The vestibule is the middle part.

b. The semicircular canals are on one side of the vestibule.

c. The cochlea, a spirally coiled tube, is on the opposite side of the vestibule.

IV. THE PATH OF THE SOUND WAVES.

Trace the path of the sound waves through the drum, the tympanic bones, the liquids in the labyrinth to the auditory nerve.

B. A Test for Hearing.

Apparatus. A watch.

a. Sit in a chair and have some one hold a ticking watch at the side of one ear. How far can the watch be carried before it ceases to be audible? Test the other ear to see if it is equally acute.

b. Hold a ticking watch between the teeth and notice how loud it ticks. Close both ears and notice the result. Repeat and uncover one ear.

C. Location of Sound.

Apparatus. Two rods of iron to make a distinct sound.

Blindfold a person and see how well sounds in front, at the back, and at the sides may be located.

XX.

SOME DERMAL SENSATIONS.

Touch, Smell, and Taste.

A. The Sense of Touch.

I. LOCATION OF TOUCH.

Close the eyes and have some one touch some part of the body. Can you name the part touched?

II. THE SENSIBILITY OF THE SKIN.

Apparatus. A pair of dividers,

Apply the blunted points of a pair of dividers simultaneously to some part of the body, as the finger tips, the back of the hand, and the back of the neck. Determine the distance between the two points that is necessary in order that the points may be felt as two. Compare your results with those given in any physiology.

III. ARISTOTLE'S EXPERIMENT.

Cross the middle finger over the forefinger, and with the crossed ends rub along the bridge of the nose. What is the sensation felt?

B. The Sense of Temperature.

Materials. Iron rods. Pieces of fur, silk, wood, and metallic rods. Water.

Apparatus. Bunsen burner. Large beakers or basins.

I. PERCEPTION OF TEMPERATURE.

a. Close the eyes and have some person touch different parts of the body with cold and warm rods. How are the sensations different?

b. With fur, wood, and metal of the same temperature test the body. Which feels colder? Why?

II. ESTIMATION OF TEMPERATURE.

Plunge the hand into water of different temperatures and so learn to judge the temperature of water. How hot can you endure the water? Can the hands or the feet endure warmer water? Plunge one hand into hot water, the other in cold, and then both into warm water. What is the sensation in each hand?

C. The Sense of Pressure.

Apparatus. Weights of different sizes.

ESTIMATION OF WEIGHTS.

a. Lift weights of different magnitude until you are able to judge some of the more common, as a pound, three pounds, etc.

b. Hold a pound weight in the hand. Add a few ounces. What is the least difference that you are able to perceive?

D. The Senses of Taste and Smell.

Materials. Sugar, vinegar, salt, pepper, apple, potato, onion, ammonia, and cabbage.

I. THE LOCATION OF THE SENSE OF TASTE.

Place a little sugar on the tip and on the back of the tongue. Where is it sweeter? Repeat with acetic acid or vinegar and salt, and determine where they are more sharply tasted.

II. THE DIFFERENCE BETWEEN TASTE AND SMELL.

Close the eyes and nostrils and try to distinguish between salt and pepper, apple and potato.

Which of the following have taste, and which have odors, — onion, sugar, salt, vinegar, carrot, dilute ammonia, and cabbage?

XXI.

THE LARYNX AND THE VOICE.

A. The Larynx.

Material. The larynx of a calf or a sheep. If possible, obtain a specimen of the larynx with the tongue and surrounding organs still attached.

I. THE DIFFERENT ORGANS OF THE SPECIMEN.

Identify:

- a.* The trachea, or windpipe.
- b.* The larynx, or cartilaginous box, at the upper end of the trachea.
- c.* The œsophagus, or gullet, a muscular walled tube running parallel with the trachea. Notice how it is attached to the larynx.
- d.* The tongue. How is it held in place?
- e.* The hyoid bones, at the root of the tongue, holding it in position. Where are they attached?
- f.* Some glands may be present in your specimen.
- g.* Sketch.

II. THE TRACHEA.

Review the structure of the trachea.

III. THE LARYNX.

Remove the fat, the blood-vessels, the lower part of the

œsophagus, most of the tongue, the muscles of the pharynx, and so expose the larynx.

Notice :

- a.* The general size and shape.
- b.* The front or **ventral surface** is easily identified by the projection in the cartilage called the **Adam's apple**.
- c.* The **epiglottis** is the lid at the upper opening.
 1. What is its shape?
 2. Raise it.
 3. Press it down and see how it closes the opening.
 4. Cut it to find its structure.
- d.* The **vocal cords** are the two elastic pads seen when looking into the larynx. Notice them when closed and when open.
- e.* The **mucous membrane** lines the larynx. Notice how it also lines the œsophagus.
- f.* The cartilages.
 1. The large cartilage on the ventral side extending backward and comprising most of the larynx is the **thyroid cartilage**.
 - (1) What is the exact shape?
 - (2) The hyoid bone is attached to its upper dorsal corner.
 - (3) At the lower dorsal corner, the thyroid is articulated with the cricoid cartilage. Notice carefully the articulation.
 - (4) The Adam's apple is on this cartilage.
 2. The **cricoid cartilage** can be found on the ventral side just below the thyroid. It resembles one

of the cartilaginous rings of the trachea and might easily be mistaken for one. Move it up and down to see that it is separate from the thyroid and the trachea. Trace it around to the dorsal side underneath the lower posterior corner of the thyroid cartilage. How far on the dorsal side does it extend? What is its exact shape? How is it articulated with the thyroid cartilage?

3. On the dorsal side above the cricoid cartilage on either side is an **arytenoid cartilage**. It is concealed by the muscles and the vocal cord, but its exact shape can be found after dissecting the muscles.

g. The muscles.

1. A **crico-thyroid** muscle is on either side of the dorsal surface extending from the thyroid to the corresponding cricoid cartilage.
 - (1) Where is it attached on each cartilage?
 - (2) What is its use?
 - (3) Dissect it away and find how the motion of the thyroid is limited.
2. The **posterior crico-arytenoid** muscles are on the posterior surface of the cricoid, one at either side. They extend diagonally upward to the corresponding arytenoid cartilages. Dissect away the attachment on the thyroid cartilage, pull the muscle, and note the effect on the arytenoid cartilage and on the vocal cord.

3. The **lateral crico-arytenoid** stretches from the lateral portion of the upper edge of the cricoid, upward and backward to the arytenoid cartilage. Disarticulate the thyroid and cricoid of one side, push aside the thyroid without injury to the muscles, and this muscle can be readily seen. Pull the muscle and note the result.
4. The **arytenoid** muscle may be found by cutting away the tissue above the cricoid cartilage at the back of the arytenoid cartilages. Cut through the middle and also see where it is attached to the arytenoid cartilages. Find where the arytenoid cartilages articulate with the cricoid. Pull the arytenoid muscle and find its use.
5. The **thyro-arytenoid** muscle extends from the ventral surface of the thyroid across to the arytenoid. Cut it at its origin, dissect it loose, and prove its effect on the vocal cord.

h. Sketch a dorsal, a ventral, and a lateral view of the larynx.

i. Carefully examine from the inside the muscles of the opposite side, showing the effect of each on the vocal cords.

j. Remove all the muscles and find the exact shape of the cartilages.

k. Make a paper model of the cartilages of the larynx.

XXII.

THE BACTERIA.

A. The Harmless or Non-Pathogenic Bacteria.

Materials. Nutrient gelatin made of 500 grms. of lean beef, finely minced, 1 litre of water, 100 grms. of gold-label gelatin, 10 grms. of peptone, 5 grms. of salt, and sodium carbonate. One egg.

Apparatus. Steam sterilizer, or kettle for steaming. Hot-air sterilizer, or oven for sterilizing with gas stove. Double boiler. Stirring rod. Funnel. Filter-paper. Ring-stand. Bunsen burner. Litmus paper. Cotton-batting. Two glass flasks holding 500 c.c. each.

To make the nutrient gelatin, mix the beef with the water and allow it to stand about twelve hours. Filter through "cheese-cloth," and to the filtrate or meat-water add the gelatin, peptone, and water. Mix thoroughly in the double boiler and heat for about half an hour. Neutralize by adding sodium carbonate, till red litmus paper just turns blue. Boil for about an hour, add an egg to clarify and settle the albuminous matter, and boil a few minutes longer. Filter while hot through filter-paper into sterilized flasks and plug with cotton. Care should be taken to keep the unfiltered gelatin hot, and to wet the filter-paper with hot water before beginning to filter. Sterilize the gelatin in a steam generator twenty-five minutes a day for three days in succession. If the gelatin is found to be acid at the beginning of filtration, it

should be neutralized again and boiled for fifteen minutes. If thoroughly sterile, this nutrient gelatin should keep a long time.

I. BACTERIA IN WATER AND ICE.

Materials. 3 c.c. of water from the faucet. 20 c.c. of nutrient gelatin. A small piece of ice.

Apparatus. Two sterilized Petri dishes. (Caution. Keep the dishes covered, and do not remove the cover till your materials are ready to use.)

a. Pour the water into one of the Petri dishes, and then add 10 c.c. of the nutrient gelatin which has been warmed and so become liquid. Cover as soon as possible, to prevent the bacteria in the air from falling into the gelatin. Mix the gelatin and the water by gently rotating the dish. Label the dish carefully, giving the material examined, the date, and your name on a piece of paper placed under the dish. Keep in a darkened place at about the temperature of 24° C. Watch from day to day, and as the colonies of bacteria appear, study them. In performing the experiments alone, several check experiments should be made, but the results of the other members of the class will serve as check experiments.

Notice:

1. The number of colonies. Each colony started from a single bacterium in the water. How many bacteria were there in the water?
2. The shape of the colonies as seen from the surface and from the side. What effect do they have on the gelatin?

3. The color of the colonies. What colors do you find?

b. Ice may be examined by melting it and examining the water obtained, as in *a*.

1. Should ice be placed directly in drinking water?
Why not?
2. How may drinking water be cooled?

II. BACTERIA IN MILK.

Materials. 3 c.c. of fresh milk. 10 c.c. of nutrient gelatin.

Apparatus. A sterilized Petri dish.

Pour the milk and then the warm nutrient gelatin into a Petri dish. Mix the water and gelatin and label the culture. Keep in a warm, dark place and watch from day to day for the appearance of the colonies. Compare these colonies with those obtained from the examination of drinking water. Study these in the same way.

III. BACTERIA IN DUST.

Materials. A little dust gathered from the floor, the top of the door, or back of a picture. 10 c.c. of nutrient gelatin.

Apparatus. A sterilized Petri dish. A compound microscope.

a. Pour the warm nutrient gelatin into the dish and scatter a little dust over it. Place in a warm room and watch for the appearance of the colonies. Compare these with the colonies obtained from the examination of water and milk.

b. Mount a little dust in water on a glass slide and examine with the compound microscope. What do you find?

IV. BACTERIA IN THE AIR.

Material. 30 c.c. of nutrient gelatin.

Apparatus. 3 sterilized Petri dishes.

a. Pour 10 c.c. of the warm nutrient gelatin into a Petri dish, and allow it to stand for two minutes uncovered and exposed to the air of the room. Then cover and place with the other tests. Study the colonies as they appear.

b. Test in the same way the air of a room before and after sweeping and compare your results.

1. Why are hardwood floors more healthful than carpets?
2. Which is better, a cloth or a feather duster? Why?

V. BACTERIA IN VINEGAR.

Materials. A few c.c. of mother-of-vinegar.

Apparatus. A compound microscope, glass slide, and cover-glass.

Mount a few drops of mother-of-vinegar on a glass slide, examine with the microscope, and study the bacteria.

Notice:

a. Their size, shape, and motion.

b. In what are the bacteria embedded? This mass of jelly is called a *zoöglea*. It is formed by many individuals whose cell-walls have become mucilaginous. If the mass is membranous, as in the mother-of-vinegar, it is called *mycoderma*, or fungus-skin.

VI. THE MICROSCOPICAL EXAMINATION OF BACTERIA.

Materials. Colonies of bacteria obtained from samples of water and milk.

Apparatus. A compound microscope.

Mount on a glass slide a drop of the liquid containing bacteria. Cover with a cover-glass and examine with high power.

Notice :

- a. The size of the bacteria.
- b. Their shape and motion.

B. The Pathogenic Bacteria.

Materials. Prepared slides of cultures of the bacteria that produce typhoid fever, diphtheria, consumption, and splenic fever.

Apparatus. A compound microscope.

Examine with the microscope prepared slides of bacillus typhi abdominalis (typhoid fever), bacillus diphtheriæ (diphtheria), bacillus tuberculosis (consumption), and bacillus anthracis (splenic fever). Study as in A. VI. Do you find any cilia?

- a. What other diseases are caused by bacteria?
- b. How is the body able to combat the bacteria?
- c. What is susceptibility to disease?
- d. What is immunity from disease?
- e. Is consumption hereditary? Explain the most common "cures" for consumption.
- f. What is one method of treatment for diphtheria?
- g. What is antitoxine? How is it obtained?
- h. What is vaccination? Give reasons for and against it.

C. Putrefaction.

THE CAUSE OF PUTREFACTION.

Materials. 300 c.c. of hay infusion. To make hay infusion, pour hot water on hay, allow it to stand a few hours and then filter through paper.

Apparatus. 3 glass flasks. Cotton-batting. Cork to fit one flask.

Pour 100 c.c. of hay infusion into each flask and boil for an hour. Allow the first flask to stand uncorked. Cork the second air-tight while boiling. Plug the third with cotton-batting while boiling. Allow the three to stand side by side on the table and watch from day to day. Explain the results.

- a.* Why will preserves keep in a thick syrup?
- b.* Why are pickles preserved in vinegar?
- c.* Why does tripe keep in brine?
- d.* Explain the conditions in canned beef.

D. Conditions Necessary for the Growth of Bacteria.

I. HEAT.

Materials. 300 c.c. of fresh milk. Ice.

Apparatus. 3 bottles. Hot water-bath. Bunsen burner.

a. Pour 100 c.c. of fresh milk in one bottle. Cork it and place it on ice.

b. Pour 100 c.c. of the milk in another bottle. Cork it and allow it to stand on the table.

c. Boil for an hour the other 100 c.c. of milk in the third bottle, plug the bottle with cotton-batting and allow it to stand on the table.

d. Compare the three from day to day. Souring of milk is due to the presence of certain bacteria. They convert the milk sugar into lactic acid which gives the sour taste and curdles the milk.

1. In which of the three bottles is the best growth of bacteria?
2. What is the effect of extreme heat and cold upon bacteria?
3. Why does food keep in refrigerators?
4. Does frozen beef decay? Why not?

II. MOISTURE.

Material. 10 c.c. of nutrient gelatin.

Apparatus. A Petri dish.

Pour the warm nutrient gelatin into a Petri dish and allow it to stand uncovered for several days.

- a.* Do the colonies of bacteria appear?
- b.* How long do they grow?
- c.* What happens to them?
- d.* What happens to the bacteria if the disk is placed in a windy place?
- e.* Are the bacteria blown about when moist or dry? This is a common source of infection in contagious diseases.
- f.* Should infected matter from the sick room be allowed to dry?
- g.* What should be done with it? Is moisture necessary to the growth of bacteria?
- h.* Why does ham keep?

III. LIGHT.

Materials. 10 c.c. of nutrient gelatin.

Apparatus. A sterilized Petri dish. Black paper.

Pour the liquid nutrient gelatin into the dish and expose it two or three minutes to the air. Why? Cover and paste a piece of black paper over half of the dish and expose it to strong sunlight in an ordinary room. Watch it from day to day and notice the result. Explain.

a. Is light or darkness more favorable to the growth of bacteria?

b. Which are more healthful, sunny or dark rooms? Why?

c. What three conditions have you found essential to the growth of bacteria?

E. Milk.

Since milk is a good food and furnishes proper nutriment for the growth of bacteria, it becomes a serious matter to keep milk free from bacteria.

I. THE CONTAMINATION OF MILK.

a. Sources of contamination.

b. Prevention of contamination.

c. Laws in regard to handling milk by milk-men.

d. Adulteration of milk.

1. Why is milk adulterated?

2. What chemicals are most often used?

II. THE PRESERVATION OF MILK.

a. Preservatives. Sometimes various chemicals are added to prevent souring. What is used for this purpose?

b. The sterilization of milk.

1. Recall experiment **D. I.** How long did the boiled milk keep sweet? How does boiling affect the taste of milk? If the milk is heated hot enough to kill all the infectious germs, a scum appears on the top which is the albumin of the milk coagulated by heat. A boiled taste is also acquired which is objectionable to some persons, though very pleasant to others. Milk thus heated is a little less digestible than fresh milk. If a high degree of heat is used, the sugar is scorched, and this forms a brown sediment on the bottom of the dish.

c. The Pasteurization of milk.

Materials. Milk. Water.

Apparatus. Pasteurizing apparatus or tin pail. Thermometer. Bunsen burner. Stand. Bottles. Cotton-batting.

The Pasteurization of milk may be easily done in any home.

Fill one or more bottles nearly full of milk and plug with dry, clean cotton-batting. The apparatus for Pasteurizing consists of a large tin pail which has a false tin bottom perforated with holes. The cover should fit tightly and have a thermometer held in place by a cork in an opening. Place the bottles in an upright position in the pail and fill the pail with enough water to rise above the milk in the bottles. Close the pail and heat over a Bunsen burner until the water is 155° F. (if in winter) or 180° (in summer). Then remove the pail and keep tightly cov-

ered for half an hour. A cloth over the pail will help to retain the heat. Take out the milk bottles, cool as quickly as possible in cold water or on ice, and keep in a cold

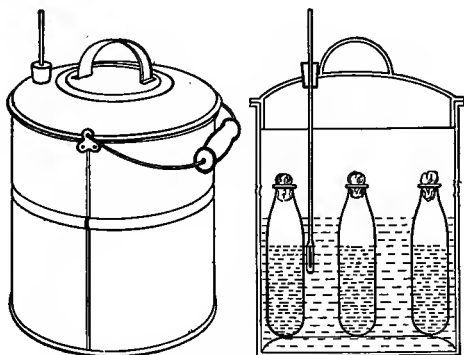


FIG. 19. — Apparatus for Pasteurizing Milk.

place. The cotton plugs should be kept dry and not removed until the milk is to be used.

a. Taste the milk to determine if its flavor has been changed.

b. Keep the bottles at the ordinary temperature of the room. How long does the milk keep before souring?

c. Is the milk germ free? Prove it.

F. Disinfection.

By disinfection we mean killing all the bacteria and their spores. Bacteria may be killed in several ways.

I. THE ACTION OF CHEMICALS.

Materials. 2 c.c. of a (1 to 1000) solution of corrosive sublimate.
4 c.c. of milk. 20 c.c. of nutrient gelatin.

Apparatus. Two sterilized Petri dishes.

a. Pour 10 c.c. of the warm nutrient gelatin into a sterilized Petri dish. Add the corrosive sublimate and thoroughly mix it with the gelatin by rotating the dish. Add 2 c.c. of the milk and mix it with the gelatin.

b. Pour 10 c.c. of the warm gelatin into the other Petri dish. Add 2 c.c. of the milk. Place the two dishes under the same conditions of heat and light and watch for results from day to day. Explain.

1. What other chemicals are used as disinfectants?
2. How do they disinfect?
3. What danger is there in their use?
4. When may chemicals be safely used as disinfectants?
5. When may they not be used?

II. THE EFFECT OF HEAT.

a. Recall experiment A. I. *b.*

Does freezing kill bacteria?

b. Recall experiments C. I and D. I.

Does boiling or exposure for three quarters of an hour at 100° C. by means of steam kill bacteria?

c. Some foods and liquids would be injured by exposure for three quarters of an hour to so high a temperature as 100° C. How was the nutrient gelatin sterilized? This method is called **discontinuous sterilization**. The gelatin was subjected to a temperature of 56° C. for three or four hours on three successive days.

1. Were all the bacteria killed on the first day?
What happened to the spores?
2. What took place on the second and third days?

- d.* 1. Recall experiment E.
2. Is Pasteurized milk sterile?

e. How were the flasks and Petri dishes sterilized? This method is **hot-air sterilization**. The objects need to be subjected to a temperature of 150° C. for three quarters of an hour in dry air. What kind of objects are best sterilized in this way?

G. Purification of Water.

Read upon the following subjects : —

1. Purification of water by sand filtration. Describe a filtration plant such as is used to filter the drinking water of the city of Lawrence, Mass., or Albany, N. Y.
2. Domestic filters. Their efficiency.
3. Sterilization of water by heat.
4. Purification of water by sedimentation.
5. Purification of water by agitation with solid particles and subsequent subsidence.
6. Chemical precipitation.
7. Purification of sewage.

H. Epidemics.

Give the history of one epidemic, either of typhoid fever or of diphtheria.

- a.* Its cause and extent.
- b.* Its means of spreading.
- c.* Remedies.

APPENDIX.



A LIST OF SPECIMENS NEEDED.

1. A human skeleton.
2. Pieces of bone to burn.
3. Slender (rib) bone to place in acid.
4. Long bones.
5. Tabular bones.
6. Short bones.
7. Irregular bones or vertebræ.

NOTE. — Numbers 4, 5, 6, and 7 may be obtained at the market, from the table, or found already cleaned in the fields. Partial skeletons of a dog, a horse, a bird, or a cow are very useful.

8. The axis and atlas.
9. A fresh long bone sawed longitudinally.
10. Part of a skeleton to clean and mount.
11. A ball-and-socket joint of an ox, a hip-joint.
12. The fore leg of a sheep.
13. Fœtal bones of some young animal, as a pig.
14. A chicken or fowl.
15. A small piece of corned beef.
16. Fresh blood.
17. The heart and lungs of a sheep.
18. Frogs.
19. Different kinds of human teeth.
20. A kidney of a sheep.
21. The brain of a sheep.

22. The spinal cord of some large animal.
23. The eye of an ox.
24. The larynx of a calf or sheep.
25. A living cat.
26. A rabbit.
27. Saliva.
28. The teeth of horse, dog, and cat.
29. A few drops of human blood.

NOTE. — The skeleton and other bones may be obtained of Ward's Natural History Establishment, Rochester, N. Y.

A LIST OF MICROSCOPICAL SLIDES.

1. Circulation of the blood in the web of the foot of a frog.
2. Cross-section of adipose tissue.
3. " " " a human humerus bone.
4. " " " developing bone.
5. " " " the skin of the head.
6. " " " the spinal cord, cervical region.
7. " " " the spinal cord, dorsal region.
8. " " " the spinal cord, lumbar region.
9. " " " the brain.
10. " " " a nerve ganglion.
11. " " " a tooth.
12. " " " the wall of the stomach.
13. " " " the small intestine.
14. " " " the liver.
15. " " " a muscle.
16. " " " the pancreas.
17. A radial section of kidney.
18. Fresh human blood, a few drops.
19. Hyaline cartilage.
20. Milk.

21. Plain muscle fibres.
22. Potato starch grains.
23. Saliva.
24. Slide of bacillus typhi abdominalis.
25. " " " diphtheriæ.
26. " " " tuberculosis.
27. " " " anthracis.
28. Stained corpuscles of the blood of the frog.
29. Striated muscle fibres.
30. Typical cells, as the cells in the cast-off skin of a newt or frog.

NOTE. — Numbers 1, 18, 20, 22, and 23 may be prepared before the class exercise. The other slides may be obtained of Bausch & Lomb Optical Company, Rochester, N. Y.

A LIST OF MODELS.

1. A manikin.
2. A model of the brain.
3. " " " " eye.
4. " " " " ear.
5. " " " " heart.
6. A wooden model of the arm.
7. A model of the valves of the aorta.
8. " " " " chest to show the vertical enlargement.
9. " " to show the dorso-ventral enlargement of the chest.
10. The circulation apparatus of glass and rubber tubing.
11. The lever apparatus.
12. A paper model of the larynx.

NOTE. — The models numbers 6, 7, 8, 9, and 12 are to be made by the student. Most of the other models may be obtained of Ward's Natural History Establishment, Rochester, N. Y., or of Mr. Charles H. Ward, Rochester, N. Y.

A LIST OF CHEMICALS AND OTHER SUPPLIES.

- | | |
|--|-------------------------------|
| 1. Acetic acid. | 30. Beans. |
| 2. Alcohol. | 31. Beef, lean. |
| 3. Ammonium chloride. | 32. Bread. |
| 4. Ammonium hydrate. | 33. Butter. |
| 5. Barfoed's solution. | 34. Cabbage. |
| 6. Benzine. | 35. Cane sugar or saccharose. |
| 7. Borax. | 36. Carrot. |
| 8. Chloroform. | 37. Cheese. |
| 9. Chrome alum. | 38. Corn meal. |
| 10. Corrosive sublimate. | 39. Cornstarch. |
| 11. Cupric sulphate, 10 per cent solution. | 40. Crackers. |
| 12. Fehling's solution. | 41. Dates. |
| 13. Formalin. | 42. Dextrose. |
| 14. Gelatin, gold label. | 43. Eggs. |
| 15. Hydrochloric acid. | 44. Farina. |
| 16. Iodine. | 45. Glue. |
| 17. Lime-water. | 46. Grapes. |
| 18. Nitric acid. | 47. Ice. |
| 19. Normal salt solution. | 48. Indian meal. |
| 20. Pancreatin, Fairchild's. | 49. Lactose. |
| 21. Pepsin, Fairchild's. | 50. Maple sugar. |
| 22. Peptone. | 51. Maple syrup. |
| 23. Potassium bichromate. | 52. Milk. |
| 24. Potassium ferrocyanide. | 53. Molasses. |
| 25. Rennet. | 54. Oatmeal. |
| 26. Sodium hydrate. | 55. Olive oil. |
| 27. Sodium carbonate. | 56. Onions. |
| | 57. Peas. |
| | 58. Pepper. |
| 28. Apples. | 59. Potato. |
| 29. Barley. | 60. Prunes. |

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| 61. Rice. | 66. Tapioca. |
| 62. Rye. | 67. Turnips. |
| 63. Sago. | 68. Vinegar and mother-of-vinegar. |
| 64. Salt. | |
| 65. Starch. | 69. Whole wheat flour. |

NOTE. — “Barfoed’s Solution. Make a solution of neutral acetate of copper containing 1 part of the salt to 15 parts of water. To 200 c.c. of this solution add 5 c.c. of a 38 per cent solution of acetic acid.

Fehling’s Solution. Solution *A*. 34.64 grams of pure crystalline cupric sulphate are powdered and dissolved in 500 c.c. of distilled water. Solution *B*. In another vessel dissolve 173 grams of Rochelle salts (sodio-potassium tartrate) in 100 c.c. of pure caustic soda, sp. gr. 1.34, and add water to make 500 c.c. Keep the two solutions separate in stoppered bottles, and mix them as required. On mixing equal quantities of *A* and *B*, a clear deep blue fluid is obtained.” — *Stirling’s Practical Physiology*.

A LIST OF APPARATUS.

1. A compound microscope giving a magnification of about six hundred diameters.
2. A hand magnifying glass; the tripod is convenient.
3. A set of instruments for each student, composed of —
 1. One scalpel, No. 5435 (Cat., Fifteenth Edition);
 2. One pair of scissors, No. 5585;
 3. One pair of forceps, No. 5825;
 4. One blowpipe, No. 5910;
 5. Two needle holders, No. 5970.
4. Pencils, hard and medium.
5. Colored crayons, red, blue, yellow, and green.
6. Air-tight box for killing rabbit. (The crock for waste material may be used.)

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| 7. Beakers. | 16. Cotton-batting. |
| 8. Bell-jar. | 17. Cotton, white. |
| 9. Bulb syringe. | 18. Cover-glasses. |
| 10. Bunsen burner. | 19. Double boiler. |
| 11. Bone forceps. | 20. Double convex lens. |
| 12. Candle and stand. | 21. Evaporating dish. |
| 13. Cardboard. | 22. Fasteners. |
| 14. Colored paper. | 23. Filter-paper. |
| 15. Colored worsteds. | 24. Force-pump. |
25. Fulcrum, or triangular prism of wood.
26. Funnel.
27. Fur, a small piece.
28. Gimlet.
29. Glass bottles.
30. Glass bottle with flat sides.
31. Glass flasks, two, 500 c.c. each.
32. Glass rods, 35 c.m., of 2 m.m. in diameter.
33. Glass rods, for stirring rods.
34. Glass slides.
35. Glass tubing.

Three-way glass connecting tubing, Y-shape.

Six large size, 12 m.m. in diameter, length of one arm, 90 m.m.

Eight medium size, 6 m.m. in diameter, length of one arm, 65 m.m.

Two medium size, T-shaped, 6 m.m. in diameter, length of one arm, 65 m.m.

Sixteen small size, 4 m.m. in diameter, length of one arm, 60 m.m.

36. Glass tubing of different sizes.
37. Glass tubing, 50 c.m. 12 m.m. in diameter.
38. Granite-ware stew-pan.
39. Ground-glass screen.

40. Hot-air sterilizer or oven.
41. Knitting needle or probe.
42. Litmus paper.
43. Lamp-chimney.
44. Meat-saw.
45. Mortar and pestle.
46. Needles and thread.
47. Pair of dividers.
48. Pasteurizing apparatus or tin pail.
49. Petri dishes.
50. Pinch-cocks.
51. Pins.
52. Ring-stand.
53. Rods of wood and metal.
54. Rotary apparatus with color disks. Bradley Color Wheel
and Maxwell Disks.
55. Rubber dam.
56. Rubber tubing.
 - 660 c.m. pure rubber tubing, 12 m.m. in diameter.
 - 1½ metre pure rubber tubing, 6 m.m. in diameter.
 - 560 c.m. pure rubber tubing, 5 m.m. in diameter.
57. Ruler or tape-measure.
58. Scales, Fairbanks' Standard.
59. Sheet-cork.
60. Sponge.
61. Spring-balance.
62. Steam sterilizer or kettle for steaming. May use the
Pasteurizing apparatus.
63. Test-tubes.
64. Test-tube rack.
65. Test-types for testing eyes.
66. Thermometer, chemical.
67. Thermometer, physician's.

68. Twine.
69. Watch-crystals.
70. Water-bath.
71. Weights of different sizes.
72. Wire, fine.
73. Wire-gauze.
74. Wooden pail.
75. Wooden rods for levers.
76. Dr. Fitz's lever apparatus.

NOTE 1. — References as to the kind of apparatus are to the catalogues of Bausch and Lomb Optical Company.

NOTE 2. — When time permits there are other more difficult experiments that may be introduced as class exercises. The apparatus for such experiments may be obtained of the Waltham Clock Co., Waltham, Mass.

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INDEX.

A.

Abducens, 102.
Absorption, 83, 84.
Accommodation, 118.
Acetabulum, 19.
Acetic acid, 73, 83, 85, 129.
Adam's apple, 131.
Adjustment, 3, 4.
After-images, 124.
Agitation, 145.
Air, 50, 51, 137.
Albino, 117, 118.
Albumin, 142.
Albuminoid, 14.
Alcohol, 75, 93, 95.
Alveolus, 66.
Ammonium chloride, 75.
 hydrate, 14, 16, 73, 129.
Amylopsin, 81.
Animals, 117.
Antitoxine, 138.
Aorta, 38, 39.
Apex of heart, 36.
Apparatus, 151-154.
Appendix, 61, 147-155.
Apple, 67, 129.
Aqueduct of Sylvius, 103.
Arachnoid membrane, 96.
Arch, 90.
Areas, motor, 100, 101.
 sense, 100, 101.

Aristotle's experiment, 127.
Arm, 2, 26, 29, 100, 101.
Artery, 38, 39, 43, 44, 50, 66.
Articular extremities, 11.
 process, 12, 13.
Astigmatism, 119.
Atlas, 12, 13.
Auricles, 37, 38, 41.
Axis, 12, 13, 113.
 cylinder, 105, 110.
Axon, 105, 110.

B.

Bacillus, anthracis, 138.
 diphtheria, 138.
 tuberculosis, 138.
 typhi abdominalis, 138.
Back, 106.
Bacteria, 77, 134-145.
Baking powder (see sodium carbonate).
Barley, 69.
Base of heart, 36.
Bausch & Lomb Optical Co., 5, 149.
Beans, 69.
Beats of heart, 41.
Beef, 23, 75, 82, 134, 139, 140.
Belly of a muscle, 22.
Benzine, 76.
Biceps, 24, 28.
Bicuspid, 39, 56.

- Bile duct, 62, 66.
 Binocular vision, 120.
 Bipenniform, 24.
 Blind spot, 115, 116, 120.
 Blister, 90.
 Blood, 31, 48.
 arterial, 34.
 circulation, 35.
 clotting, 32.
 color, 34.
 flowing, 44.
 human, 31.
 of frog, 31.
 of hen, 32.
 of pigeon, 32.
 principles of circulation, 43.
 structure, 31.
 venous, 34.
 -vessels, 23, 37, 43, 65, 87, 88,
 89, 107, 116, 130.
 Bodies, restiform, 99.
 Body, 26, 43, 51, 57, 58, 100, 127,
 128, 138.
 of the compound microscope, 2.
 of gland, 92.
 pituitary, 100.
 Bone, 9, 10, 11, 12, 13, 14, 15.
 anvil, 126.
 developing, 21.
 hard, 11.
 hyoid, 130, 131.
 irregular, 9.
 long, 9.
 microscopical structure, 15.
 short, 9.
 spongy, 11, 13.
 stirrup, 126.
 tabular, 9.
 tympanic, 126.
 Books of reference, 154, 155.
 Borax, 16.
 Brain, 94-105, 108, 110, 111, 124.
 Bread, 69.
 Breathing, 52.
 Brine, 139.
 Bronchial tubes, 50.
 Bronchus, 50.
 Bulb, spinal, 96, 99.
 Butter, 75, 76, 81.

C.

 Cabbage, 67, 129.
 Calcium carbonate, 14.
 phosphate, 14.
 Calf, 29, 106, 130.
 Calices, 88.
 Canal, 107, 126.
 alimentary, 59, 63, 83.
 Canaliculi, 15.
 Candle-flame, 117, 118.
 Cane-sugar (see saccharose).
 Canine, 56, 59.
 Capillaries, 42, 44.
 Carbohydrates, 67, 72, 81.
 Carbon dioxide, 51.
 Cardboard, 16, 17.
 Cardiac orifice, 60.
 Card-test, 119.
 Carnivorous animals, 57.
 Carpal bones, 18.
 Carpets, 137.
 Carrot, 67, 129.
 Cartilage, 8, 11, 19, 20, 21.
 arytenoid, 132, 133.
 cricoid, 131, 133.
 thyroid, 131, 132, 133.
 Casein, 73, 74, 81, 83.
 Cat, 93, 117, 119, 120.
 Cavity, abdominal, 58, 63.
 body, 109, 112.
 buccal (see mouth).

- Cavity of bone, 11.
 of brain (see ventricles).
 thoracic, 58.
 Cells, 7, 8, 15, 66, 91, 102, 103.
 cartilage, 20.
 epithelial, 77, 84, 105.
 hepatic, 66.
 muscle, 105.
 nerve, 105, 107, 108, 110.
 Cell-wall, 7.
 Cement, 56.
 Centres, 101.
 Centrum, 12.
 Cerebellum, 96, 97, 98, 99, 100, 104.
 Cerebral hemispheres, 97, 103.
 Cerebrum, 96, 97, 100.
 Cervical region, 108.
 swellings, 106.
 Chamber of eye, 114, 115, 116.
 Check experiments, 135.
 Cheek, 90.
 Cheese, 74.
 Chemicals, 141, 143, 150, 151.
 Chest, 51, 52.
 Chiasma, optic, 100, 104.
 Chicken, 22.
 Chloroform, 108, 109, 110, 111.
 Chordæ tendinæ, 39.
 Choroid coat, 114, 115, 118.
 Chromatin loops, 7.
 Chrome alum, 120, 121.
 Cilia, 138.
 Circle, 120.
 Circulation, principles of, 43.
 Clark-Maxwell's experiment, 120.
 Clips, 2.
 Clock, 119.
 Clot, 33, 83.
 Cloud, 121.
 Coat, 110, 116.
 Cochlea, 126.
 Cœcum, 61.
 Cohnheim, areas of, 25.
 Collagen, 14.
 Colon, 61.
 Colonies, 135, 136, 140.
 Color, 123, 136.
 Color-blindness, 123.
 -disks, 123.
 Column, spinal (see vertebral column).
 Columns, posterior, 99, 108.
 Compositions of food, 67.
 Concentric structure, 69.
 Concha, 125.
 Conjunctiva, 114.
 Consumption, 138.
 Contamination, 141.
 Contents, vii.
 Convolutions, 97, 104.
 Cord (see tendons).
 Cord, spinal, 94, 103, 106, 107, 108, 110, 111, 112.
 vocal, 131, 132, 133.
 Cornea, 113, 114, 115, 118, 119.
 Cornstarch, 69.
 Cornua, 107, 108.
 Corpora quadrigemina, 97, 99, 100, 102.
 Corpus callosum, 103, 104.
 striatum, 104.
 Corpuscles, red, 31, 42.
 white, 31, 42.
 Cortex, 88, 101, 102.
 Cot, rubber, 86.
 Coverings, 95.
 Crackers, 69.
 Cream, 75.
 Creases, 89.
 Cross, 120.
 Crown of tooth, 55.
 Crura cerebri, 96, 100, 101, 102.

Crypts of Lieberkühn, 65.
 Culture, 136.
 Cupric sulphate, 73, 74.
 Curd, 80, 83.
 Curdle, 140.

D.

Dates, 72.
 Débris of food, 67.
 Defects in vision, 118.
 Dendrites, 105.
 Dentatum corpus, 105.
 Dentine, 56.
 Dermis, 90, 91, 92.
 Dextrose, 70, 71, 72, 84, 85.
 Diaphragm, 2, 4, 35, 52, 59, 61.
 Diffusion, 84.
 Digestion, 55-66.
 organs of, 58, 76, 77-86, 112.
 Diphtheria, 138, 145.
 Directions, general, 1-6.
 Diseases, 138, 140.
 Disinfectants, 144.
 Disinfection, 143.
 Distribution, 109.
 Dog, 93, 117, 125.
 Drawings, 5.
 Draw-tube of compound micro-
 scope, 2, 4.
 Drum, 125, 126.
 Duct, 66, 92, 116.
 Dust, 136.
 Duster, 137.

E.

Ear, 94, 125, 126.
 Egg, 72, 75, 76, 84, 85.
 -albumin, 72, 74, 75, 79.
 Elbow-joint, 29.

Emulsion, 75, 76.
 Enamel, 56.
 Epidemic, 145.
 Epidermis, 42, 89, 91, 92.
 Epiglottis, 59, 131.
 Ether, 76, 93.
 Eustachian tubes, 59, 125.
 Examination of object, 3.
 Experiments, records of, 6.
 Extension, 100.
 Eye, 4, 113-124, 129, 134.
 Eyebrows, 116.
 Eyelashes, 117.
 Eyelids, 114, 116.
 Eyepieces, 1, 3.

F.

Farina, 69.
 Farsight, 118.
 Fasciculi, 23.
 Fat, 67, 75, 113.
 globules, 76, 81, 82, 87, 130.
 Fatigue, 27, 124.
 Fever, splenic, 138.
 typhoid, 138, 145.
 Fibres, 8, 102, 103, 105, 108, 114.
 medullated or white, 110.
 nerve, 109, 112.
 non-medullated or gray, 110.
 Fibrillæ, 25.
 Fibrin, 31, 33.
 Fibula, 15.
 Field, visual, 119.
 Figures, 122.
 Filters, 145.
 Filtration, 145.
 Finger, 26, 90, 118, 127.
 -prints, 90.
 Fissure, 96, 97, 102, 104.
 dorsal, 107.

Fissure, median, 103.
 of Rolando, 98.
 of Sylvius, 98.
 parieto-occipital, 98.
 ventral, 107.
 Flexion, 100.
 Floors, 137.
 Flour, wheat, 69, 76, 81, 82.
 whole wheat, 76.

Fluid, 77, 88, 107.
 Focus, 4.
 Fœtus, 21.
 Follicle, 92.
 Foods, 67, 76.
 Foot, 1, 29, 100, 111, 128.
 Foramen of Monroe, 103.
 Forearm, as lever, 28.
 Fore-brain, 96.
 Forehead, 90.
 Fore leg of lamb, 20.
 Formalin or formaldehyde, 95, 108,
 109, 112.
 Formula, dental, 56, 59.
 Fowl, 16, 23, 24.
 Frog, 27, 31, 32, 40, 41, 108, 111,
 112.
 Fulcrum, 28.

G.

Gall bladder, 62.
 Ganglia, 94, 109, 110.
 Gas-jet, 124.
 Gastric glands, 63, 65.
 juice, 78, 79, 80, 81, 82.
 Gastrocnemius muscle, 27.
 Gelatin, 14, 134, 135, 136, 137,
 140, 141, 143, 144.
 Germ, 142, 143.
 Gimlet, 16.
 Gland, 62, 63, 65, 66, 130.

Glasses, 118.
 Globe, 124.
 Glottis, 59, 60.
 Glue, 85.
 Grapes, 70.
 Gullet, 130.

H.

Hair, 91, 116.
 Hairless place, 116.
 Ham, 140.
 Hammer, 125.
 Hand, 26, 43, 89, 90, 127, 128.
 Haversian canals, 15.
 Head of bone, 19.
 Hearing, 125, 126.
 Heart, 35, 36, 37, 38, 40, 43.
 Heat, 143, 144.
 Herbivorous animals, 57.
 Hereditary characteristics, 7.
 Hilum, 69.
 Hilus, 87.
 Hind-brain, 96, 98.
 Hip-joint, 18, 19.
 Humerus, 10, 15, 30.
 Humor, 114, 115, 116.
 Huxley, viii.
 Hydrochloric acid, 13, 14, 71, 72,
 78, 79, 80, 81, 82, 112.
 Hypermetropia, 118.

I.

Ice, 135, 136.
 Image, 117, 120, 124.
 Imbibition, 84, 85.
 Immunity, 138.
 Impulse, nerve, 110, 112.
 Incisor, 56, 59.
 Incus, 125.

Infection, 140.
 Infundibulum, 100.
 Infusion, 139.
 Ink, 84, 85, 90.
 Insertion of muscle, 22.
 Instruments, 6.
 Intestine, 109, 112.
 large, 61, 63, 64.
 small, 61, 63, 64, 84.
 Iodine, 68, 69.
 Iris, 114, 117, 119.
 Irradiation, 121.

J.

Joints, 18-21.
 ball and socket, 18, 19.
 gliding, 18.
 hinge, 18.
 muscles of, 30.
 pivot, 18.
 Judgments, imperfect visual, 121,
 122.

K.

Kidney, 87, 88, 112.
 Knee, 110.
 -jerk, 110.
 -joint, 18.
 pan, 110.
 Knuckles, 26.

L.

Labyrinth, 126.
 Lacteal, 65.
 Lactic acid, 140.
 Lactose, 70, 71, 72, 140.
 Lacunæ, 15.
 Lamb, fore leg, 22.

Lamellæ, 15.
 Lamp, 119.
 Larynx, 130-133.
 Leg, 29.
 Leitz microscope, 3.
 Lens, 3, 115, 116, 117.
 capsule, 115.
 Letters, 122.
 Levers, 28, 29.
 Lieberkühn, crypts of, 65.
 Ligaments, 19.
 capsular, 19, 20.
 round, 19.
 Light, 4, 100, 141.
 Lime, 85.
 -water, 73, 74.
 Liquid, 90, 126.
 Liver, 62, 66.
 Lobe, frontal, 98.
 lateral, 105.
 occipital, 98.
 olfactory, 98.
 parietal, 98.
 temporal, 98.
 Lobes, 66.
 Lobules, 66.
 Loop, 90.
 Lumbar swellings, 106.
 Lungs, 35, 49, 53.

M.

Magnification, 2, 3.
 Malleus, 125.
 Malpighian bodies, 88.
 Maltose, 70, 71, 78.
 Marriott's experiment, 120.
 Marrow, 11, 12.
 Mater, dura, 95.
 pia, 96, 107.
 Matrix, 21.

Matter, gray, 102, 103, 104.
 infected, 140.
 mineral, 13.
 white, 103.
 Meal, Indian, 69, 76.
 Meatus, external auditory, 125.
 Medulla oblongata, 96, 99, 102,
 103, 105.
 Medullary cavity, 11, 13.
 portion, 88.
 Membrane, epithelial, 84.
 mucous, 114, 116, 131.
 of cord, 107.
 Mesentery, 62.
 Microscope, 1-5.
 Mid-brain, 100.
 Milk, 73, 76, 78, 80, 81, 82, 83,
 136, 139, 141, 142, 143, 144, 145.
 Milk-men, 141.
 -sugar (see lactose).
 Milled head, 3, 4.
 Mirror, 3, 4.
 Mitral valve (see bicuspid valve).
 Model of arm, 29, 30.
 chest, 52, 53, 54.
 circulation, 44, 45, 46.
 ear, 125.
 larynx, 133.
 lever, 28, 29.
 valves of aorta, 46, 47.
 Moisture, 140.
 Molar, 56, 59.
 Molasses, 72.
 Motor oculi, 102.
 Mouth, 59.
 Mucous coat, 64, 65.
 Muscles, 16, 22-30.
 action of, 27.
 arytenoid, 132.
 ciliary, 114.
 crico-arytenoid, 132.

Muscles, crico-thyroid, 132.
 gross structure, 23.
 groups, 100, 101.
 kinds, 23.
 microscopical structure, 24.
 of eye, 113.
 papillary, 39, 74.
 simple, 24.
 thyro-arytenoid, 133.
 Muscular coat, 64, 65.
 Mycoderma, 137.
 Myopia, 118.
 Myosin, 75.

N.

Nasal openings, 59.
 Nearsight, 118.
 Neck, 55, 90, 106, 111, 127.
 Nerves, 23, 89, 94.
 auditory, 102, 126.
 cranial, 101.
 facial, 102.
 glosso-pharyngeal, 102.
 hypoglossal, 102.
 olfactory, 101.
 optic, 100, 101, 113, 115, 120.
 pneumogastric, 102.
 spinal, 109, 112.
 spinal accessory, 102.
 sympathetic, 94, 112.
 trunks of, 112.
 Network, 108.
 Neural arch, 12.
 canal, 12.
 ring, 12.
 Neuron, 105.
 Newt, 7.
 Nitric acid, 14, 74.
 Normal salt solution, 109.
 Nose, bridge of, 116, 127.

Nostril, 129.
 Nucleolus, 7, 108.
 Nucleus, 7, 25, 31, 91, 107, 110.

O.

Oatmeal, 69.
 Objectives of compound micro-
 scope, 1, 3.
 Odors, 129.
 Oesophagus, 35, 60, 63, 130, 131.
 Oil, glands, 92.
 olive, 82, 84.
 Onion, 67, 129.
 Openings, 10, 89, 116.
 Ora serrata, 115.
 Organs, 112, 130.
 circulatory, 112.
 digestive, 58, 112.
 excretory, 112.
 Origin of muscle, 22.
 Osmosis, 84.
 Ossein, 14.
 Outflow, 46.
 Ox, 113.
 Oxid cuprous, 70.
 Oxygen, 34.

P.

Pail, 142.
 Palm of hand, 89, 90.
 Pancreas, 66, 131.
 Pancreatic juice, 81, 83.
 Pancreatin, 81, 83.
 Papers, 124.
 Papilla, 57, 89, 92.
 Paste, starch, 78.
 Pasteurization, 142.
 Pathetici, 102.
 Peas, 69.

Peduncles, 96, 99, 100, 104.
 Pelvis, 88.
 Penniform, 24.
 Pepper, 129.
 Pepsin, 78, 79, 80, 81.
 Peptone, 134.
 Peptonized, 83.
 Pericardial liquid, 35.
 Pericardium, 35, 41.
 Perimysium, 23.
 Periosteum, 10.
 Peritoneum, 63.
 Person, 93, 123, 126.
 Perspiratory glands, 89, 92.
 Pharynx, 59.
 Pickles, 139.
 Pigeon, 22.
 Pillar of the compound micro-
 scope, 1.
 Pineal gland, 100.
 Piotrowski reaction, 72.
 Pits, 65.
 Pituitary body, 100.
 Plain muscle, 25, 26.
 Pluck, 35.
 Pons Varolii, 96, 99, 102, 104, 105.
 Potassium bichromate, 95, 113,
 115.
 ferrocyanide, 73
 Potato, 67, 68, 129.
 Pound, 128.
 Power, 28.
 Precipitation, 145.
 Preface, iii-v.
 Premolar, 59.
 Preservatives, 141.
 Preserves, 139.
 Pressure, 128.
 Process, 13, 115.
 Processes, branched (seedendrites).
 Products of digestion, 83.

Prominences, 11.

Proteids, 67, 72-75, 78, 81.

Protein (see proteid).

Protoplasm, 7, 8, 107.

Prunes, 72.

Pulp cavity, 56.

Pulse, 43, 45.

Pump, 45.

Pupil, 114, 117, 119.

Purification, 145.

Putrefaction, 139.

Pyloric orifice, 61.

Pyramids, 99.

of Malpighi, 88.

R.

Rabbit, 94.

Radius, 30.

Rays, 121.

Record of experiments, 5, 6.

Rectum, 61, 62.

Reducing agent, 70.

sugar, 71.

Reflex action, 110, 111, 112.

Rennet, 80.

Rennin, 78, 80, 81.

Resistance, peripheral, 43.

use of, 46.

Respiration, 49-54.

number of, 51.

Retina, 115, 116, 118, 121, 124.

Rice, 69.

Ridges, 10, 89.

Rings, cartilaginous, 49.

Rods, 128.

Rooms, 141.

Root, 91, 92.

of nerves, 101, 106, 107, 109.

of tooth, 55.

Rough places on bone, 10.

S.

Saccharose, 71, 72.

Sago, 69.

Saliva, 77, 78.

Salt, 129.

Salts, 67, 70.

Sarcolemma, 25.

Sarcoplasm, 25.

Scapula, 30.

Sclerotic coat, 113, 114, 117, 118.

Screen, 117.

Sebaceous glands, 92.

Sediment, 142.

Sedimentation, 145.

Semilunar valves, 39.

Sensations, 123, 127-129.

Septa, 107.

Serum, 33, 34.

Sewage, 145.

Shade, 119.

Shaft of a long bone, 10, 11.

Sheath, 109.

Sheep, 94, 130.

Shoes, rubber, 86.

Shoulder-blade, 9.

-bone (see scapula).

-joint, 30.

Skeleton, 9, 10, 16, 17, 18.

Sketches, 5.

Skin, 87, 89-93, 127.

Skull, 94, 100, 101.

Slides, microscopical, 148.

Smell, 127-129.

Sodium carbonate, 81, 134.

hydrate, 73, 74.

Barfoed's, 70, 71.

Solution, Fehling's, 70, 71, 72.

Sound, 126.

Souring of milk, 140, 141, 143.

Specimens, 147, 148.

- Spinous process, 12.
 Spleen, 62.
 Spores, 143, 144.
 Spot, 121.
 Spring-balance, 28.
 Squares, 120, 121.
 Stage, 2.
 Stand of the compound microscope, 1, 4.
 Staples, 125.
 Starch, 68, 69, 72, 77, 81.
 Steapsin, 81.
 Stem of hair, 92.
 Sterilization, 134, 142, 144, 145.
 Stimulus, 111, 112.
 Stomach, 60, 63, 64, 79, 80..
 Striations of muscle, 24, 25.
 Sublimate, corrosive, 143, 144.
 Submucous coat, 65.
 Subsidence, 145.
 Substance, gray, 105, 107, 108.
 white, 103, 105, 107, 108.
 Sugar, cane (saccharose), 71, 72, 129.
 grape (dextrose), 70, 71, 72, 85, 84.
 maple, 72.
 milk (lactose), 70, 71, 72, 140, 142.
 reducing, 71.
 Summer, 142.
 Sunlight, 141.
 Susceptibility, 138.
 Sweat glands, 89, 90.
 Sweeping, 137.
 Sweet, 142.
 Swellings, 106.
 Synovial liquid, 20.
 membrane, 19, 20.
 Syrup, 72, 139.
 System, cerebro-spinal, 112.
 nervous, 94-112.
 sympathetic, 112.
 Systole, 41.
- T.**
- Tadpole, 42.
 Tapioca, 69.
 Taste, 127-129, 142.
 Teeth, 55, 59, 126.
 Temperature, 50, 89-93, 127, 128.
 Tendons, 19, 22, 24, 26.
 Test for hearing, 126.
 Test-types, Snellen's, 118.
 Tetanus, 27.
 Thalamus, optic, 104.
 Thermometer, 142.
 Thorax, 52, 53, 54.
 Throat (see pharynx).
 Thumb, 26, 90.
 Tissue, cellular, 95.
 connective, 8, 66, 108, 109.
 epithelial, 8.
 fatty, 8.
 fibrous, 95.
 nervous, 94.
 Toes, 27.
 Tongue, 53, 57, 129, 130, 131.
 Touch, 127.
 Trachea, 35, 49, 52, 130, 132.
 Tracts, optic, 100, 101, 103.
 Transverse processes, 12.
 Triceps, 29, 30.
 Trigeminals, 102.
 Tripe, 139.
 Trypsin, 81.
 Tuber cinereum, 100.
 Tubules, 88.
 Turnip, 67.
 Tympanum, 125.
 Type, 118.

U.

Ulna, 30.
 Ureter, 87, 88.
 Uriniferous tubules, 88.
 Use of the microscope, 4.

V.

Vaccination, 138.
 Valve, 38, 39, 40, 46.
 Valvulæ conniventes, 64.
 Vein, 38, 39, 40, 43, 44, 50.
 Veinlet, hepatic, 66.
 Venæ cavæ, 37, 38.
 Ventricle, of brain, 99, 103, 104.
 of heart, 36, 37, 38, 41.
 Vertebra, 12, 112.
 Vertebral column, 12, 112.
 Vestibule, 126.
 Villi, 64, 65.
 Vinegar, 14, 73, 83, 84, 85, 129,
 137, 139.
 Vision, 113-124.
 Voice, 130-133.

W.

Watch, 126.
 Water, 67, 128, 135, 136, 145.
 Waves, sound, 126.
 Weight, 28, 128.
 Whey, 80.
 Whorl, 90.
 Windpipe, 130.
 Winter, 142.
 Wire, 16.
 Wisdom teeth, 57.
 Worsteds, 123.
 Wrist, 9, 18, 43.

Y.

Yellow spot, 120.

Z.

Zanthoproteic reaction, 72.
 Zöllner's lines, 122.
 Zoöglea, 137.

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